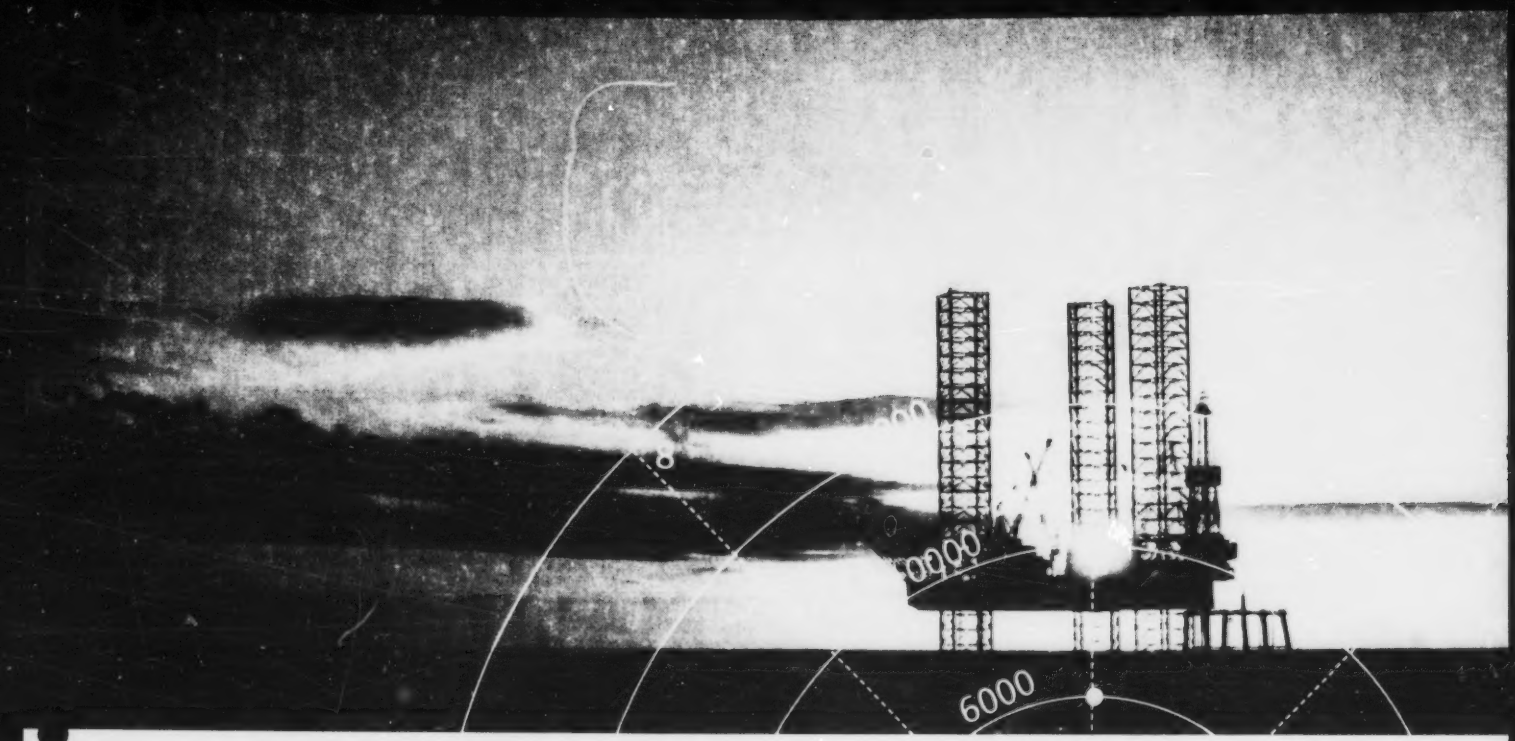

UNDERSTANDING THE ENVIRONMENTAL EFFECTS OF OFFSHORE HYDROCARBON DEVELOPMENT

PROCEEDINGS OF A WORKSHOP

Co-sponsored by
Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG)
and
The Bedford Institute of Oceanography

March 2-3, 2000

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Proceedings of a Workshop Co-Sponsored by the Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG) and the Bedford Institute of Oceanography, March 2-3, 2000

D.C. Gordon, Jr., L.D. Griffiths, G.V. Hurley, A.L. Muecke, D.K. Muschenheim, and P.G. Wells (Editors)

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A MESSAGE FROM JOHN BRANNAN, GENERAL MANAGER AND PRESIDENT, SOE INC.

ENERGY FROM BENEATH THE SEA

SOE Inc. is pleased to have sponsored this highly successful workshop, together with the Bedford Institute of Oceanography. Over three hundred people, representing the oil and gas industry, the scientific community, fishers, regulators and environmental managers. First Nations and community and environmental organizations, participated in two days of constructive information sharing and discussions. We were especially pleased to see so many students in attendance.

When SOE Inc. submitted its Development Plan Application we made the following statement:

The proponents consider protection of the environment essential to the integrity of ecosystems, human health and the well-being of society. This will be a measure of the success of this development over it Project life of 25 years or more.

Environmental effects monitoring is a crucial part of SOE Inc.'s follow-up program to ensure that we are keeping our commitment to environmental stewardship. We established SEEMAG to help us with this task, and. in turn, SEEMAG organized this workshop so that we can all learn from each other's experiences.

SOE Inc. continues to work with stakeholders to ensure the sound management of our ocean resources and the conservation of marine habitats.

John K. Brannan
President and General Manager
Sable Offshore Energy Inc.

"Sustainable development does not all lie in the future; it requires making the present and the future work together."

Percy Haynes, Fisherman, Gulf of St Lawrence

SUMMARY

The offshore oil and gas industry in Atlantic Canada is rapidly developing. Oil production began at CoPan in 1992 and Hibernia in 1997. First gas was produced on Sable Island Bank in late 1999 and oil production at Terra Nova is scheduled to begin in 2001. CoPan shut down in December 1999, but other offshore fields are expected to be developed in the near future. This activity is having major economic, environmental and social consequences for Atlantic Canada.

There is wide recognition that these non-renewable hydrocarbon resources should be developed in an environmentally responsible manner taking into account the concerns of all stakeholders. A regulatory framework has been established under the Canada Newfoundland and Canada Nova Scotia Offshore Petroleum Boards. Environmental effects monitoring (EEM) programs have been conducted at the four production sites. In addition, a number of government and university research programs of relevance to EEM programs are being conducted.

In 1998, Sable Offshore Energy Incorporated (SOE Inc.) created the Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG) to provide advice on the design and implementation of their EEM. During its deliberations, SEEMAG decided it would be beneficial to sponsor an open forum at which all stakeholders could come together to discuss the environmental impacts of offshore hydrocarbon developments in Atlantic Canada.

This recommendation was accepted by SOE Inc. and a workshop was subsequently organized by SEEMAG and held at the Bedford Institute of Oceanography on 2-3 March 2000. It was attended by over 300 people representing government research laboratories, universities, regulatory agencies, the oil and gas industry, environmental consultants, the fishing industry, First Nations, and environmental organizations. The purpose of the workshop was to a) share information on relevant research projects and industry-sponsored EEM programs, b) review from a wide range of viewpoints the lessons learned to date, and c) to discuss the way forward. This was accomplished through a series of invited review talks, poster papers and discussions.

It was recognized that an extensive scientific data base on the effects of offshore hydrocarbon development is available from other regions, especially the North Sea and the Gulf of Mexico, and that basic principles can be applied from one region to another. Valuable resources can be wasted by repeating unnecessary studies, and there is much to learn from experience elsewhere. By and large, Canadian environmental effects research has focused on issues and conditions unique to Atlantic Canada, and has included a broad range of integrated projects covering physical oceanography, sedimentology, chemistry, toxicology and ecology. Most projects fall under the categories of drilling wastes, produced water or oil spills, and are being conducted using a variety of laboratory, field and modelling approaches. Products of this research relevant to EEM programs include new knowledge of environmental processes, effects of contaminants on marine organisms, field instrumentation and predictive numerical models. However, it was emphasized that the marine ecosystems of Atlantic Canada are very complex and undergo pronounced natural variations that are poorly understood despite many years of study. This complicates the task of detecting the environmental impacts in EEM programs.

The four offshore EEM programs conducted to date, funded by industry, are asking relevant questions and have been well planned and executed. They have built upon experience in other countries and have benefited from Atlantic Canada's rich expertise in marine science,

ecotoxicity and environmental monitoring. Their scope has gradually evolved based upon experience, with the newer EEM programs generally including more valued ecosystem components (VECs) and environmental variables.

Many lessons have been learned from the limited Canadian experience on offshore hydrocarbon EEM monitoring. First and foremost is the value of having a transparent process for planning, conducting and reporting results that is open to all interested stakeholders. It is important to develop trust among all parties. The effects of offshore hydrocarbon development depend very much upon environmental conditions. Contaminants tend to disperse rapidly in shallower, high energy environments, but be more persistent at deeper sites.

Risks tend to be greater in the nearshore area than offshore. This environmental variability must be taken into account when deciding the VECs, sampling design, and variables to measure in individual EEM programs. In all cases, it is imperative to include an adequate number of reference stations outside the influence of the development to measure natural variability. It is also important to make maximum use of numerical models to predict environmental effects, design EEM programs, and interpret results. Results to date indicate that contaminants can be carried considerable distance under some conditions, but observed effects seem to be restricted close to the release point as predicted. There have been few surprises, but most of the original predictions were quite conservative. However, it is premature to draw firm conclusions since most of the EEM programs are still in their infancy.

There were no specific recommendations for changing the existing offshore EEM programs but it was recognized that they should be reviewed regularly and modified where necessary on the basis of results. There may be valid reasons to discontinue measuring some variables but also to start measuring others if unsuspected effects are observed. There may also be reasons for incorporating new methodology. It should always be kept in mind that effects could be occurring that can not be detected above natural variability. However, numerous suggestions were brought forth for improving the overall environmental assessment process. It was noted that there is no energy policy in Atlantic Canada against which individual development proposals can be assessed. Several improvements to the existing regulatory process were recommended, in particular soliciting more input from all stakeholders before decisions are made. As offshore industrial activities continue to increase, there is a growing need for cumulative environmental impact assessment and monitoring. It was recommended by some that environmental assessment should take more of an ecosystem approach, incorporate the principles of conservation biology and make more use of the precautionary principle. Specific concerns were raised about the environmental impacts of hydrocarbon exploration in coastal waters, specifically in the southern Gulf of St. Lawrence, and the need to give more scientific attention to nearshore issues. Despite the progress made in developing trust in recent years, there is still a need for more consultation and improved communication.

RÉSUMÉ

L'industrie du pétrole et du gaz extracôtiers se développe rapidement au Canada atlantique. La production de pétrole a débuté à CoPan en 1992 et à Hibernia en 1997. Du gaz a été produit pour la première fois sur le banc de l'île de Sable à la fin de 1999 et la production pétrolière à Terra Nova devrait commencer en 2001. Le champ CoPan a été fermé en décembre 1999, mais on s'attend à ce que d'autres champs extracôtiers soient exploités dans un proche avenir. L'activité pétrolière et gazière a des conséquences économiques, environnementales et sociales majeures au Canada atlantique. On s'entend largement sur le fait que ces ressources d'hydrocarbure non renouvelables devraient être exploitées d'une manière qui soit compatible avec l'environnement et qui tienne compte des préoccupations de toutes les parties intéressés. On a donc mis en place un cadre réglementaire régi par les Offices des hydrocarbures extracôtiers Canada – Terre-Neuve et Canada – Nouvelle-Écosse. Par ailleurs, ces programmes de surveillance des effets sur l'environnement (SEE) ont été mis en oeuvre dans les quatre lieux de production. Enfin, divers programmes de recherche gouvernementaux et universitaires pertinents pour la SEE sont en cours.

En 1998, la Sable Offshore Energy Incorporated (SOE Inc.) a créé le Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG), le chargeant de formuler des avis sur la conception et la mise en oeuvre de son programme SEE. Au cours de ses délibérations, le SEEMAG a jugé qu'il serait utile d'organiser un forum libre où tous les intéressés pourraient venir discuter des effets de l'exploitation des hydrocarbures extracôtiers sur l'environnement au Canada atlantique. La SOE Inc. ayant accepté cette recommandation, un atelier fut organisé subséquemment par la SEEMAG. Il eut lieu les 2 et 3 mars 2000 à l'Institut océanographique de Bedford. Il réunissait plus de 300 personnes, représentant les laboratoires de recherche gouvernementaux, les universités, les organes de réglementation, l'industrie du pétrole et du gaz, des consultants en environnement, l'industrie de la pêche, les Premières nations et des organisations oeuvrant dans la protection de l'environnement. Cet atelier visait à : a) partager l'information sur les programmes de recherche pertinents et sur les programmes SEE mis sur pied par l'industrie; b) examiner, selon tout un éventail de perspectives, les leçons tirées jusqu'ici et c) discuter de la voie à suivre. Ces objectifs furent poursuivis au moyen d'exposés par des conférenciers invités, de communications affichées et de discussions.

On a convenu qu'une vaste base de données scientifiques sur les effets de l'exploitation des hydrocarbures extracôtiers existait déjà dans d'autres régions, en particulier en Mer du Nord et dans le golfe du Mexique, et que les mêmes principes fondamentaux sont susceptibles de s'appliquer d'une région à une autre. Des ressources précieuses peuvent être gaspillées dans la répétition d'études inutiles et il y a beaucoup à apprendre de l'expérience acquise ailleurs. De façon générale, les recherches canadiennes sur les effets environnementaux ont porté essentiellement sur les problèmes et conditions propres au Canada atlantique, incluant un grand éventail de travaux intégrés traitant de l'océanographie physique, de la sédimentologie, de la chimie, de la toxicologie et de l'écologie. La plupart de ces travaux concernent les résidus de forage, l'eau produite ou les déversements d'hydrocarbure; ils font appel à diverses techniques de laboratoire, d'observation sur le terrain et de modélisation. Pour ce qui a trait à la SEE, ces travaux ont débouché sur de nouvelles connaissances des phénomènes environnementaux, des effets des contaminants sur les organismes marins, des instruments

d'observation et des modèles de prévision numériques. On a toutefois insisté sur le fait que les écosystèmes marins du Canada atlantique sont très complexes et subissent des variations naturelles prononcées, qui sont mal comprises malgré de nombreuses années d'étude. Cela complique la détection des effets environnementaux dans les programmes SEE.

Les quatre programmes SEE du secteur extracôtier mis en oeuvre jusqu'ici soulèvent des questions pertinentes et sont bien planifiés et exécutés. Ils prennent appui sur l'expérience acquise dans d'autres pays et tirent aussi parti de la riche expertise du Canada atlantique en sciences marines, en écotoxicité et en surveillance environnementale. Leur portée a évolué progressivement selon l'expérience, les programmes SEE les plus récents intégrant en général plus d'éléments importants d'écosystème (EIE) et de variables environnementales.

De nombreuses leçons ont été tirées de l'expérience limitée du Canada dans la surveillance des effets de l'exploitation des hydrocarbures extracôtiers sur l'environnement. D'abord et avant tout, songeons à la valeur que représente un processus transparent de planification et d'exécution des activités ainsi que de compte rendu des résultats ouvert à toutes les parties intéressées. Il importe en effet d'établir la confiance entre toutes ces parties. Les effets de l'exploitation des hydrocarbures extracôtiers dépendent largement des conditions environnementales. Les contaminants tendent à se disperser rapidement dans les milieux hydrodynamiques actifs et à être plus persistants dans les milieux quiescents. Dans la zone côtière les risques tendent à être plus grands que dans la zone extracôtière. Cette variabilité environnementale doit entrer en ligne de compte lorsqu'on prend des décisions sur les EIE, sur la conception du programme d'échantillonnage et sur les variables à mesurer dans chaque programme SEE. Dans tous les cas, il est impératif d'inclure un nombre adéquat de stations de référence hors de la zone d'influence de l'exploitation pour mesurer la variabilité naturelle. Il importe aussi de tirer le meilleur parti possible des modèles numériques pour prédire les effets environnementaux, concevoir les programmes SEE et interpréter les résultats. Jusqu'ici, les résultats indiquent que les contaminants peuvent être transportés sur des distances considérables dans certaines conditions, mais que les effets observés semblent, comme on le prévoyait, limités aux abords du point de diffusion. On a connu peu de surprises, mais il faut dire que les prédictions initiales étaient assez prudentes. Il est encore trop tôt pour tirer des conclusions fermes, la plupart des programmes SEE en étant encore à leurs débuts.

On n'a pas recommandé de modifications particulières aux programmes SEE actuels mis en oeuvre dans le secteur extracôtier, mais on a convenu qu'ils devraient être réexaminés régulièrement et modifiés si nécessaire selon le résultat de ces réexamens. Il peut y avoir de bonnes raisons d'abandonner certaines variables, mais également d'en ajouter d'autres si on observe des effets inattendus. Il peut également y avoir lieu d'intégrer une nouvelle méthodologie. Il faudrait toujours avoir conscience qu'au-delà de la variabilité naturelle des effets non décelés peuvent se produire. De nombreuses suggestions ont été formulées pour améliorer le processus d'évaluation environnementale dans son ensemble. On a noté l'absence au Canada d'une politique énergétique sur laquelle se fonder pour évaluer les propositions d'exploitation. Plusieurs améliorations au processus réglementaire actuel ont été recommandées, particulièrement pour ce qui est de solliciter davantage l'opinion de tous les intéressés avant que des décisions soient prises. Au fur et à mesure que les activités industrielles extracôtières continuent de s'accroître, il y a un besoin croissant de surveillance et d'évaluation des effets cumulés sur l'environnement. Certains ont

préconisé une approche plus écosystémique à l'évaluation environnementale, qui intégrerait les principes de la biologie de conservation et ferait davantage appel au principe de précaution. Certaines inquiétudes ont été formulées quant aux effets environnementaux de la prospection des gisements d'hydrocarbures dans les eaux côtières, en particulier dans le sud du golfe du Saint-Laurent, et à la nécessité pour les scientifiques de porter plus d'attention à la zone côtière. Malgré les gains réalisés ces dernières années en ce qui concerne la confiance, de plus amples consultations et une meilleure communication restent nécessaires.

PREFACE

The idea for this workshop arose during discussions at meetings of the Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG) in 1999. SEEMAG had been formed by SOE Inc. to provide advice on the design and implementation of an environmental effects monitoring program. SEEMAG members decided that it would be beneficial to sponsor a forum where the oil and gas industry, scientists, regulators and managers, other resource users, First Nations, environmental and wildlife organizations and the public could come together to review what we now know about the environmental effects of offshore hydrocarbon development in Atlantic Canada and what we still need to find out.

The Bedford Institute of Oceanography agreed to co-sponsor the event and to provide the venue. The Canadian Association of Petroleum Producers (CAPP) sponsored a reception for workshop participants on the evening of the first day. SOE Inc. covered all other costs. The workshop was organized by a steering committee, whose members are the editors of these proceedings.

The workshop had three purposes:

- to share information on relevant research projects and industry sponsored environmental effects monitoring
- to itemize, from a wide range of viewpoints, the lessons learned to date, and
- to discuss the way forward.

On the first day, there were a series of presentations on environmental effects research and on the environmental monitoring programs associated with four East Coast offshore developments[1]. The second day began with a keynote address from a noted environmental scientist and research manager from the US, followed by a panel discussion involving observers of the oil and gas industry drawn from a number of different sectors, and an open mike discussion for all the workshop participants.

Don Gordon, Cal Ross and Ian McLaren moderated different components of the workshop, and Peter Wells closed the workshop by summarizing and reflecting on the key themes. All are members of SEEMAG.

Over 330 people registered for the workshop, about twice the number originally anticipated. Participants came from all four Atlantic Provinces, with particularly good representation from Newfoundland, a number of other provinces and the US.

The call for posters to be displayed at the workshop also received an excellent response, with about thirty people and organizations contributing posters or displays.

In order to prepare these proceedings, the steering committee asked all presenters and participants in the poster session to provide an abstract of their talks and posters. In addition we recorded the keynote address, the panel discussion and the open mike session on the second day, in order to prepare notes that were extensive though not strictly verbatim. Questions from the audience during the first day were mostly captured in the extensive notes taken by our workshop rapporteur, Peter Wells.

SEEMAG will be reviewing the main issues and findings that emerged during the workshop, and also the comments provided by participants on the feedback forms. We also encourage readers of these proceedings to send us any comments you may have and have included a tear-out comment sheet in the Appendix for that purpose. We will endeavour to incorporate appropriate

[1] Cohasset-Panuke (in the process of being decommissioned), Hibernia, Sable Offshore Energy and Terra Nova (in the design stages).

ideas and knowledge into our deliberations and recommendations to SOE Inc.

Workshop participants evidently appreciated this opportunity to share information and to discuss ideas of mutual interest to all those with an interest in sound environmental and resource management. SEEMAG hopes that there will be further opportunities to continue this process.

Sable Offshore Energy Environmental Effects Monitoring Advisory Group

SEEMAG was established in January 1998 in fulfillment of a commitment made by SOE Inc. in its Development Plan Application for the Sable Offshore Energy Project. The Group includes scientists, representatives of academic and research institutions, the fishing and aquaculture sector, First Nations, and environmental organizations. It also includes representatives from the three fisheries liaison committees that were formed by SOE Inc. to address monitoring issues arising from the interactions of the Project and the fishing and aquaculture industries.

Over the last two years, SOE Inc. has implemented an extensive program to monitor the biophysical effects of its facilities and activities on the offshore, nearshore and onshore environments. SEEMAG's role has been to advise SOE Inc. on the selection of ecosystem components to be monitored, the techniques to be used, and the interpretation of results.

More specifically, in accordance with its objectives, SEEMAG has:

- assisted in scoping the EEM program;
- ensured that the EEM program focused on significant issues identified through scientific inquiry, public consultation, or regulatory requirements;
- reviewed monitoring studies and commented on their scientific and statistical validity;
- evaluated program results and recommended improvements to the program and further mitigation measures, when necessary;
- commented on linkages between the EEM program and environmental compliance monitoring when this has been in the interests of effective environmental management;
- contributed to the understanding of the environmental impacts of the offshore oil and gas industry.

SEEMAG has met seven times since early 1998[2], and during that time has reviewed and discussed over 30 studies which cover the following areas:

- the relationship between the project construction schedule and the timing of the monitoring activities;
- the design of monitoring programs for the offshore, nearshore and Strait of Canso;
- the activities of SOE Inc.'s three Fisheries Liaison Committees;
- research into the fate of drilling wastes conducted by Fisheries and Oceans Canada through the Program on Energy Research and Development (PERD);
- scientific studies on Sable Island and The Gully;
- Codes of Practice for Sable Island and The Gully;
- marine bird studies;
- environmental controls and monitoring plans for the onshore facilities;
- environmental management plans for all aspects of the project;
- waste management plans;
- Aboriginal concerns;
- public access to the pipeline corridor.

SEEMAG organized this workshop in order to bring the scientific work on EEM in Atlantic Canada before a broader scientific, industry, and

[2] For more information about SEEMAG's activities during the first two years of its existence, see Sable Offshore Energy Environmental Effects Monitoring Advisory Group. 2000. Annual Reports 1998 and 1999. This document is available from the SEEMAG Secretariat.

non-governmental organization (NGO) audience, and to promote communication between stakeholders and better understanding of the environmental context of offshore hydrocarbon development.

As of May, 2000, the members of SEEMAG were:

Mike Coolen, Health, Safety and Environment, SOE Inc.
Meinhard Doelle, Clean Nova Scotia
Brian Giroux, Scotia-Fundy Mobile Gear Fishermen's Association and Offshore Fisheries Liaison Committee
Don Gordon, Marine Environmental Science Division, Fisheries and Oceans Canada
Bruce Hancock, Goldboro-Isaac's Harbour Fisheries and Aquaculture Liaison Committee
Geoffrey Hurley, Health Safety and Environment, SOE Inc.
Alan Kennedy, Imperial Oil Resources Limited
Bob Kerr, Mobil Oil Canada
Ian McLaren Department of Biology, Dalhousie University
Douglas Mead, Shell Canada Limited
Tim Martin, Netukulimkewe'l Commission
Kee Muschenheim, Acadia Centre for Estuarine Research
Janis Raymond, NS Fisheries and Aquaculture
Cal Ross, Health Safety and Environment, SOE Inc.
Bob Waldon, Maritimes and Northeast Pipeline Project
Charles Warner, Strait of Canso Commercial Fisheries Liaison Committee
Peter Wells, Environment Conservation Branch, Environment Canada.

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ACKNOWLEDGEMENTS

The steering committee wishes to acknowledge and thank the following individuals and organizations for helping to make the workshop a success.

- SOE Inc. for generous financial support and for the active involvement by the staff of the Health Safety and Environment Section

- BIO for providing the workshop venue, the participation of many scientists as presenters and participants, and for publishing these proceedings

- CAPP for hosting the reception on the first day, and also sponsoring the participation of over 50 post-secondary students in the workshop

- The staff and students of the following institutions
  - NSCC, Annapolis Valley Campus, Centre of Geographic Sciences
  - DalTech
  - Co-operative Education Department, Saint Mary's University
  - NSCC, Halifax Campus
  - Acadia University
  - Architecture and Urban Planning, Dalhousie University
  - Faculty of Science, Dalhousie University
  - UCCB

- Kelly Bentham for providing audio-visual advice and assistance
- Cynthia Bourbonnais, Shelley Armsworthy and Anthony Deveau for logistical assistance at the workshop
- Brian Harrison, Lou Cable Design, for design services.

Viewing the poster display

Jocelyne Hellou speaks during the open mike session

Don Gordon, DFO, Workshop Co-Chair

Cal Ross, SOE Inc., Workshop Co-Chair

The panel discussion

PART A. PRESENTATIONS AND POSTERS

INTRODUCTION AND OVERVIEW

Welcome and Opening Remarks

Donald C. Gordon Jr., *Fisheries and Oceans Canada, Bedford Institute of Oceanography*
Cal Ross, *Sable Offshore Energy Inc.*

Introduction

The workshop was called to order by the Co-Chairs Donald Gordon and Cal Ross. After a brief safety announcement, John Brannan, President and General Manager of Sable Offshore Energy Incorporated (SOE Inc.), was introduced and welcomed the large audience of scientists, managers, regulators, oil and gas industry representatives, fishing industry representatives, First Nations representatives, environmental organizations, and students.

Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG)

The workshop was organized by the Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG) and co-sponsored with the Bedford Institute of Oceanography (BIO).

The concept of SEEMAG was originally proposed by Phil Tsui during the Sable Offshore Energy Project (SOEP) environmental assessment process, and subsequently endorsed by the Joint Public Review Panel. SEEMAG was created in January 1998 and has met seven times. It is comprised of about 20 knowledgeable and experienced people from the oil and gas industry, academic and research institutions, the fishing and aquaculture sectors, First Nations, and environmental organizations. The purpose of SEEMAG is to advise SOE Inc. on what should be monitored, how should the monitoring be carried out, and what the monitoring results mean. Full details on SEEMAG are provided its Annual Report, which was distributed to all workshop participants. SEEMAG is the only group of its kind providing environmental advice for approved oil and gas projects in Atlantic Canada.

Development of the Workshop

At early meetings, SEEMAG was briefed on current research being done in Atlantic Canada which was relevant to environmental effects monitoring (EEM) of offshore hydrocarbon developments and on other industry-sponsored offshore EEM programs. Because this is important information needed by SEEMAG in formulating advice, it was proposed to have a workshop which would review the relevant research and EEM programs in more detail.

Because of the rapid growth of the oil and gas industry in Atlantic Canada, it was felt that many beyond SEEMAG would be interested in such a review, and that the workshop should be opened up to a larger audience. It was also recommended that the wider community should have a chance to comment on how the SOE Inc. EEM program is developing. A recommendation to SOE Inc. to organize such a workshop was accepted, and a Steering Committee comprised of SEEMAG members was struck in August 1999 to plan the event. BIO agreed to co-sponsor the workshop by

offering meeting space and funding the publication of the workshop proceedings. Many meetings and discussions by the Steering Committee produced the final agenda. The excellent turnout (over 300) clearly illustrates the need for such a workshop.

Purpose of Workshop

As outlined in the program, the purpose of the workshop was:

- To share information on relevant research projects and industry-sponsored environmental effects monitoring programs in Atlantic Canada. What have we learned?
- To address the lessons learned to date on environmental effects monitoring programs from a wide range of viewpoints. What are we doing right, what are we doing wrong, what are the gaps?
- To discuss the way forward on environmental effects monitoring programs. What do we still want to know and how can our EEM programs be improved?

The results of the workshop will be used by SEEMAG in formulating advice on EEM to SOE Inc. It is also hoped that they will be of value in improving other offshore EEM programs in Atlantic Canada. Another more general objective is to facilitate communication among all parties involved in protecting the marine ecosystems of Atlantic Canada from adverse impacts of our rapidly growing offshore oil and gas industry.

In organizing this workshop, SEEMAG has placed the focus on EEM programs and associated research that deal with offshore hydrocarbon developments that have passed through the regulatory approval process and are either operational or under development. Speakers for the first day were selected accordingly. Because of the limits of time, it was decided not to include EEM programs dealing with exploration and land-based activities which are equally important issues in Atlantic Canada.

Brief Review of the Agenda

Day 1 began with several introductory talks to set the stage for more technical presentations. These were followed by presentations on the four approved EEM programs (CoPan, Hibernia, SOE Inc. and Terra Nova) and on current research being conducted on the Scotian Shelf and Grand Banks that contributes to the design, operation and interpretation of offshore EEM. Most of this research has been funded by the federal Panel on Energy Research and Development (PERD). The day ended with a general question and discussion session followed by a reception sponsored by the Canadian Association of Petroleum Producers (CAPP).

Day 2 began with a poster session, which included 25 posters plus additional displays. They were up for the entire workshop so that they could be viewed during breaks and lunches. This was followed by a keynote address by Jim Ray, Manager of Environmental Sciences for Equilon Technology. Jim has many years of experience in conducting fate and effects research on offshore hydrocarbon developments. He offered some perspectives on how EEM approaches for offshore hydrocarbon development compare to those in other parts of the world, especially the US. He is no stranger to Atlantic Canada, having participated in the 1992 St. John's meeting on managing the environmental impact of offshore oil production.

The morning ended with a panel of the fishing industry and environmental organizations that gave their views on EEM monitoring programs.

After lunch, there was an open mike discussion to give the audience an opportunity to express their opinions and concerns about existing EEM programs. Questions posed included: Where should we go from here? What changes should we recommend to EEM programs? What are remaining important information gaps? The focus of this discussion was intended to be on approved EEM programs for offshore development

projects, but broader issues including exploration activities and nearshore monitoring were also raised. The full discussion was recorded and is included in these proceedings. The workshop concluded with a synthesis of highlights by Peter Wells.

Summary

This workshop was just one meeting in a long series of conferences, workshops and hearings that have been held in both Newfoundland and Nova Scotia over the past thirty years addressing the environmental implications of offshore hydrocarbon development in Atlantic Canada. It clearly will not be the last. Hopefully the proceedings will be a valuable contribution to the overall effort and help set the agendas for future gatherings.

A Retrospective Overview of Industry Activity, Scientific Research, Regulatory Framework, and the Development of Environmental Effects Monitoring Programs

Donald C. Gordon Jr., *Fisheries and Oceans Canada, Bedford Institute of Oceanography*

Purpose

The purpose of this presentation was to provide some historical background to environmental issues dealing with offshore hydrocarbon development in Atlantic Canada, especially for workshop participants new to the topic. It also served as an introduction to the principal players. It is broken down into four components: industry activity, scientific research, regulatory framework, and environmental effects monitoring programs.

Industry Activity

The hydrocarbon potential of offshore Atlantic Canada was first recognised through geological surveys done in the 1950's. Exploration permits were first issued in the early 1960's. The first exploration wells were drilled in Newfoundland in 1966 and Nova Scotia in 1967. There have been cycles of exploration activity since that time. Over 300 wells have now been drilled in Atlantic Canada. Today, active exploration programs are either planned or underway at various locations including the Grand Banks, the west coast of Newfoundland, Sable Island Bank, the Scotian Slope, and the southern Gulf of St. Lawrence. A moratorium has closed Georges Bank to drilling until at least 2012.

Substantial hydrocarbon resources have been discovered on the Grand Banks and Sable Island Bank, and four offshore developments have been approved. They are Cohasset/Panuke, Hibernia, the Sable Offshore Energy Project, and Terra Nova. Cohasset/Panuke stopped production in December 1999 and Terra Nova is scheduled to start production in early 2001. Additional developments, such as White Rose, are on the horizon.

A good way to keep informed on the rapidly growing offshore hydrocarbon industry is through Atlantic Petroleum, a magazine that serves the information requirements of companies, individuals and government agencies involved with the exploration and development of offshore oil and gas in Atlantic Canada.

Many individual companies are involved. The main industry contact is the Canadian Association of Petroleum Producers (CAPP) which represents 170 companies whose activities focus on exploration, development, and production of hydrocarbon resources throughout Canada. CAPP has its main office in Calgary but recently opened regional offices in St. John's and Halifax.

Scientific Research

There is a very large international scientific

literature on the environmental impacts of oil spills and offshore hydrocarbon development. Much of the research has been conducted in Europe (e.g. North Sea) and North America (e.g. Gulf of Mexico, east coast, Arctic). Canadian scientists have made many contributions to this international body of research, especially in the areas of oil spills and drilling wastes.

The Canadian oil spill research program began with the ARROW in Chedabucto Bay, NS, in 1970. Since then it has studied other spills, both at home and abroad. Other projects have studied oil spill trajectory modelling, fate of hydrocarbons in water and sediment, effects of hydrocarbons on marine organisms (indices including growth and reproduction, physiological variables, biochemical variables, etc.), tainting, stranding and weathering of oil on shorelines, and bioremediation.

Research on drilling wastes (muds and cuttings) started in the late 1980's just after the first drilling moratorium on Georges Bank was announced. Focus was placed on understanding processes in the benthic boundary layer where particulate drilling wastes tend to concentrate. Projects included modelling the transport of water and sediment, understanding the sedimentology of drilling wastes, developing instrumentation for field studies, and determining biological effects (with emphasis on the sea scallop). State-of-the-art numerical models have been developed which can be used to predict the effects of drilling waste discharges (from either exploration or development wells) on valuable benthic resources such as the sea scallop.

Canadian scientists have also made important contributions to improving the design and methodology of environmental impact assessment and environmental effects monitoring procedures. A new program investigating the fate and effects of produced water is just getting underway.

A broad spectrum of institutions has been involved in this research, often working in partnership. These include the federal government (e.g. DFO, EC, NRCan), universities (e.g. MUN, Dalhousie), the oil and gas industry, and environmental consultants. Funding has come from various sources including the federal Panel on Energy Research and Development (PERD), the National Scientific and Engineering Research Council (NSERC), the Environmental Studies Research Fund (ESRF), government labs and industry through partnerships.

As a result of these activities, there is a large, diverse and experienced research community in Atlantic Canada. Over the past thirty years, many workshops and conferences have been held throughout Atlantic Canada to review the results of research studying the environmental effects of hydrocarbon exploration and development activities. Many members of this scientific community were at the SEEMAG/BIO workshop. These scientists have developed both knowledge and tools that are being used today in designing and conducting offshore EEM programs, and much of the recent work relevant to offshore development EEM programs was presented.

Regulatory Framework

The regulatory framework for hydrocarbon exploration and development has evolved over the years. When exploration activities began in Atlantic Canada, the lead agency was the Canada Oil and Gas Lands Administration (COGLA). The regulatory function is now led by two offshore petroleum boards. The Canada Newfoundland Offshore Petroleum Board (CNOPB) was established under the Canada/Newfoundland Accord (1985) while the Canada Nova Scotia Offshore Petroleum Board (CNSOPB) was established under the Canada/Nova Scotia Offshore Petroleum Resources Accord (1987).

These independent boards manage offshore oil and gas resources on behalf of federal and provincial governments. They implement

regulations and make all technical decisions. They are accountable to Parliament and provincial legislatures through the federal and provincial Ministers of Energy. Their mandates include resource management, operations and safety, environmental protection, and economic benefits within their respective areas of jurisdiction. Further information can be found on their websites (cnopb.nfnet.com and cnsopb.ns.ca).

The National Energy Board (NEB), which has just turned 40 years old, also has some regulatory responsibilities in Atlantic Canada. It reports to Minister of Natural Resources Canada and its overall mandate is to promote safety, environmental protection and economic efficiency. It regulates interprovincial and international pipelines, international powerlines, exports of electricity, natural gas and oil, and exploration and development of oil and gas resources in non-Accord frontier areas (e.g. not in Newfoundland and Nova Scotia). Further information can be found on their website (neb.gc.ca).

A very important part of the regulatory framework for offshore hydrocarbon development is the environmental impact assessment (EIA) process. EIA review panels have been struck for all major development projects. These are usually done jointly under federal and provincial legislation, and consider input from all interested stakeholders, including environmental organizations, the fishing industry, First Nations and community groups. The Canadian Environmental Assessment Agency (CEAA) was present at this workshop.

Environmental Effects Monitoring Program

EEM programs have been developed for the four approved offshore development projects. They are usually based on recommendations from EIA panels supplemented with input from workshops, advisory groups, etc. These programs need to be well designed, focus on clear questions, and provide useful information that can be incorporated into project management. They are funded by industry and usually conducted by the scientific consulting community. The details of the different EEM programs vary considerably, depending in part on their environmental setting and the local resources at risk. The variables measured are evolving as experience is gained.

The four approved EEM programs are at Cohasset/Panuke (started in 1992), Hibernia (started in 1994), Sable Offshore Energy Project (started in 1998) and Terra Nova (started in 1998). The design and selected results of these four EEM programs were described in more detail later in the workshop (see pages 36 to 43).

NATURAL ENVIRONMENT AND EXPOSURE TO CONTAMINANTS

Presentations

TRANSPORT AND DISPERSION ON OFFSHORE BANKS

***Charles Hannah**, Fisheries and Oceans Canada, Bedford Institute of Oceanography*

A set of models is being developed for the transport and dispersion of suspended sediment in the benthic boundary layer on the continental shelf. The motivation is the estimation of the concentration and fate of drilling wastes from hydrocarbon drilling, particularly flocculated drill mud fines. The basic idea of the bblt (benthic boundary layer transport) models is that estimates of the horizontal velocity and bottom stress are combined with semi-empirical estimates of the sediment's vertical distribution (generally a function of bottom stress and the sediment's

settling velocity) to generate estimates of drift and dispersion. A local version of bblt neglects horizontal variations in water depth, currents and bottom stress. This simplification means that the model can be forced by current profiles from either a circulation model or observations such as a current meter mooring or an ADCP at a drilling site. At the same time it retains the effects of vertical and temporal variations in the currents which are important factors in short-term dispersion and transport. A version of bblt that allows for full spatial variability in the water depth, currents and bottom stress is under development. In its most general form, spatial bblt requires output from a 3-d circulation model to define the spatial and temporal variability of the currents and bottom stress.

The application of local bblt to the Hibernia site (Grand Banks), Cohasset (Sable Island Bank) and Georges Bank showed inter-regional variations associated with water depth and current strength. There was also a strong sensitivity to the effective settling velocity of the suspended material. The vertical distribution of the lighter sediment extended higher in the water column resulting in lower near-bottom concentrations. However the lighter sediment did not necessarily spread out more rapidly in the horizontal. Preliminary simulations at Cohasset were conducted to look at the effect of the increase in bottom stress due to surface waves. For a small settling velocity (0.1 cm/s) the addition of the surface waves to the bottom stress reduced the near-bottom concentrations by increasing the vertical extent of the sediment distribution, but had no significant impact on the drift or dispersion during the 5 day simulation. For a larger settling velocity (0.5 cm/s) the waves had a large impact because the sediment was only suspended during large wave events.

Applications to Georges Bank illustrated the joint use of the circulation and dispersion models to quantify dispersion in a spatially structured environment and to estimate potential impacts of exploratory hydrocarbon drilling (Figures 1 and 2). Modelled currents and local bblt were used to predict potential impacts from drilling waste disposal as a function of settling velocity and location on the Bank. The mean height of the suspended sediment distribution (an indicator of near-bottom concentration) increased on-bank because of the stronger currents in shallower water. The rate of horizontal spreading (diffusivity) also depended strongly on location, with larger values in water depths less than 100 m and smaller values in deeper water. These quantities were combined to provide a relative measure of local impact (expected near-bottom concentration). The spatial patterns of this relative measure were consistent with more detailed studies using observed currents and a hypothetical discharge scenario.

Significant effects are expected due to the spatial variations of the bottom stress, the mean currents, and the horizontal shear in the mean and tidal currents. Thus local bblt is a first approximation. An application of spatial bblt to Georges Bank was presented using circulation model estimates of the full 3-d structure of the mean and M2 currents (Figure 2). The dispersion due to the horizontal shear in the currents on the northern flank was clearly evident in the sheared distribution of the particles and this resulted in increased diffusivity compared with a local bblt application.

The bblt models, in conjunction with observational data, provide a quantitative framework for predicting the impacts of drilling waste discharges and interpreting environmental effects monitoring programs.

The model applications and development are part of an ongoing program funded by the Federal Panel for Energy, Research and Development (PERD) and the Department of Fisheries and Oceans. We thank Pan Canadian and Coastal Ocean Associates for the Cohasset ADCP data,

Carl Anderson for the bottom stress calculations, and our DFO collaborators in the drilling waste impacts studies.

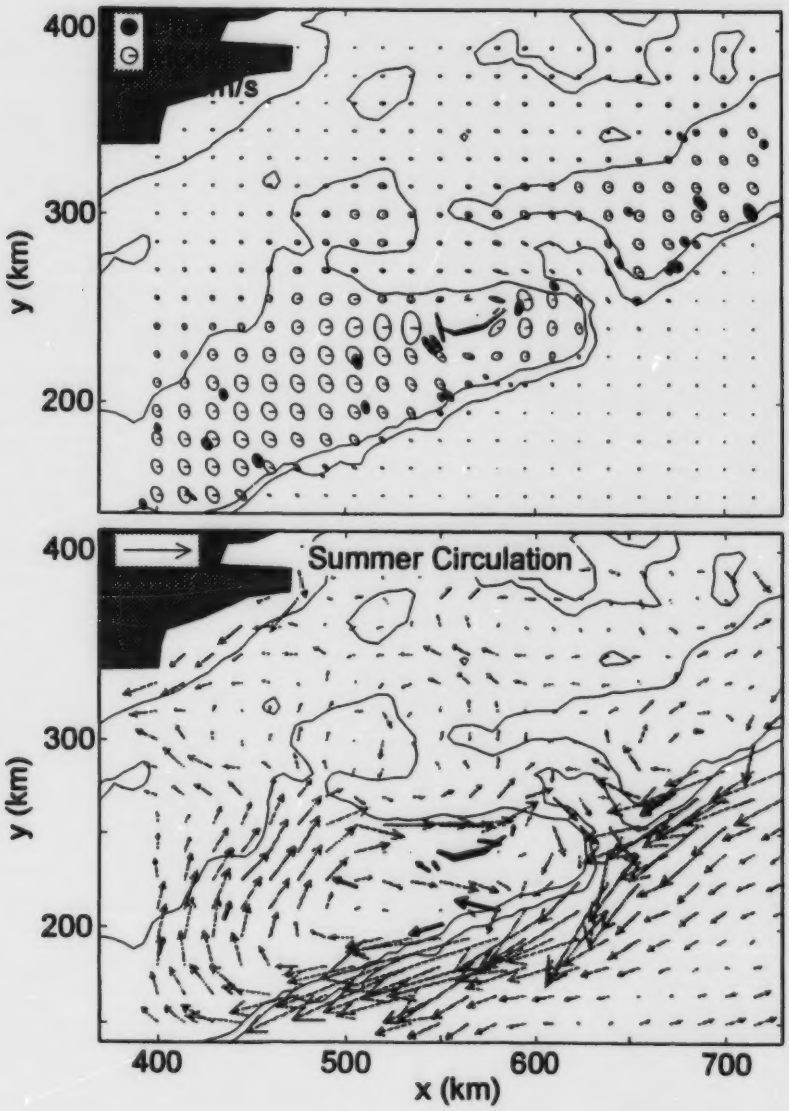

Figure 1 The upper panel shows the modelled and observed M2 tidal ellipses on Sable Island Bank and illustrates the spatial variability, with generally larger currents in shallow water. The lower panel shows the modelled (thin, grey arrows) and observed (thick, black arrows) mean summer circulation and indicates a clockwise flow around the bank and a branch of the shelf-edge flow following the topography into and out of the Gully (to the east of Sable Island).

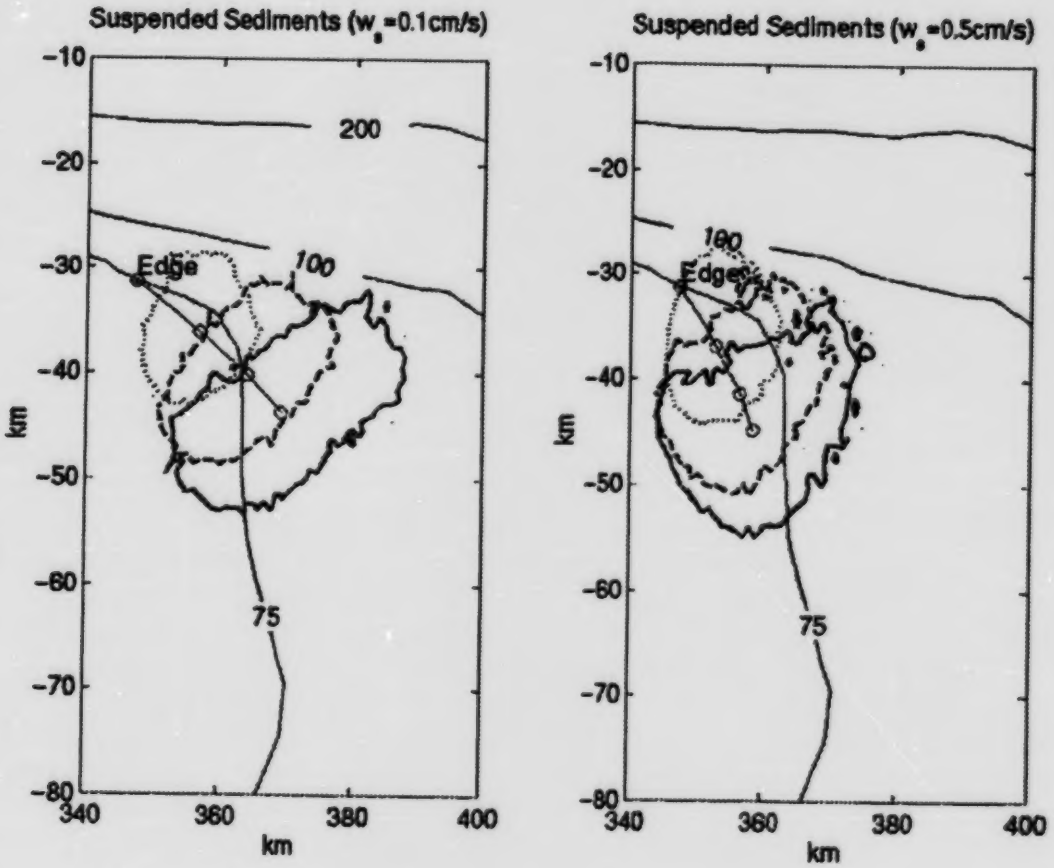

Figure 2 Patch distributions after 1 day (dotted), 2 days (dashed), and 3 days (solid) for suspended sediment distributions for a release on the northern edge of Georges Bank with settling velocity 0.1 cm/s (left panel) and 0.5 cm/s (right). The contours outline the area containing more than 90% of the material. The thin contours indicate the bathymetry in metres.

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SEABED STABILITY AND SEDIMENT DYNAMICS RESEARCH ON SABLE ISLAND BANK

***Michael Li**, Geological Survey of Canada Atlantic, Bedford Institute of Oceanography*

It is well known that strong sediment transport, seabed scouring, and formation and migration of large-scale bedforms occur on Sable Island Bank during storms. Due to the complex nonlinear relationships between waves, currents, and seabed, and the lack of simultaneous field measurements of hydrodynamics and sediment transport, our understanding of seabed stability is poor and our capability of accurately predicting sediment transport for continental shelf environments is limited.

To tackle these issues, a comprehensive seabed stability and sediment dynamics research project has been undertaken at the Geological Survey of Canada - Atlantic (GSCA). The project is mainly funded by PERD, but has benefited from support of oil/gas industry (initially Pan Canadian, Mobil, now SOE Inc.). The scientific core of the project is to understand the boundary layer dynamics and sediment transport processes on storm-dominated Scotian Shelf. Applied issues also dealt with by the project include mobile layer depth during storms and seabed scouring around offshore installations.

Sediment dynamics research is strongly linked with the environmental effect monitoring (EEM) programs. The enhanced bed shear stress and bed roughness due to the combined waves and current directly affect the resuspension and dispersion of drilling wastes. The understanding of the regional sediment transport pattern also helps make a better design of EEM programs.

The research approach of this project is (1) scientific cruises and surveys to collect baseline and background data base, (2) deployments of cutting-edge instruments to obtain in situ hydrodynamics and sediment transport data, and (3) data analyses to advance science and develop sediment transport models.

World-leading technologies in sediment transport have been developed in this project. The centrepiece of this is RALPH - an autonomous, free-standing instrumented platform for long-term in situ measurements of waves, currents and seabed responses. Other new methods and systems applied in this project include multibeam bathymetry mapping and the Imagenex Scour Monitoring System (SMS) which is a sector scanning sonar system under development for monitoring scours during storms immediately around offshore platforms.

Since 1993, nine scientific cruises/surveys have been conducted. Our instrument packages have been deployed at 15 sites on Scotian Shelf to obtain 12 good quality hydrodynamics/sediment transport data sets (Figures 3 and 4). These results have significantly advanced our understanding of boundary layer dynamics and sediment transport processes on Scotian Shelf and helped the development and calibration of the physical and regional sediment transport models - SEDTRANS

and SED94.

It is clearly established that storm processes dominate sediment transport on Scotian Shelf and that the interaction between waves and current can strongly enhance bed shear stress and bottom roughness. The thresholds for various transport modes have been established and an explicit ripple predictor has been proposed for the combined-flow conditions. With these advances incorporated, the difference between measured and model-predicted sediment transport rates has been reduced to be less than a factor of five. Some of these results have been used by DFO in predicting resuspension and dispersion of drilling wastes on Georges and Sable Island Banks. Estimates of maximum mobile layer depths during storms obtained in this project have helped SOE Inc. in choosing the final gas pipeline route.

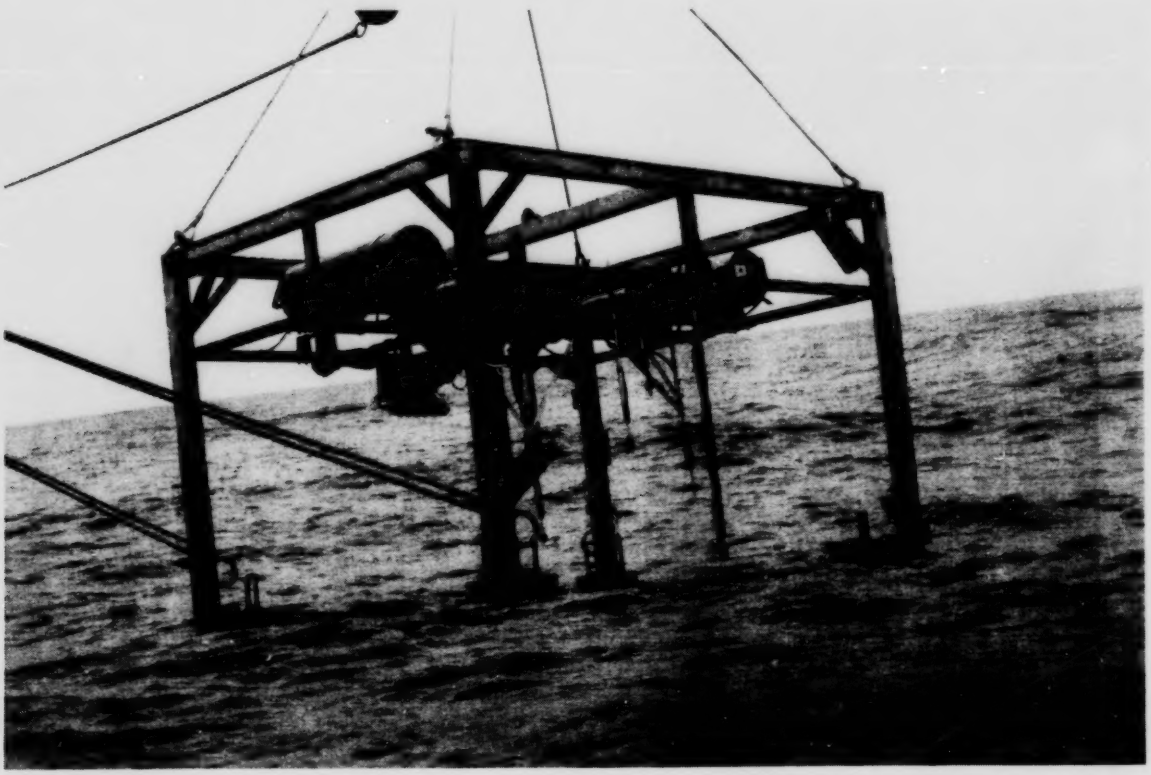

Figure 3: The GSC instrumented platform RALPH for long-term, autonomous in situ measurements of waves, currents and seabed response for sediment dynamics and seabed stability research.

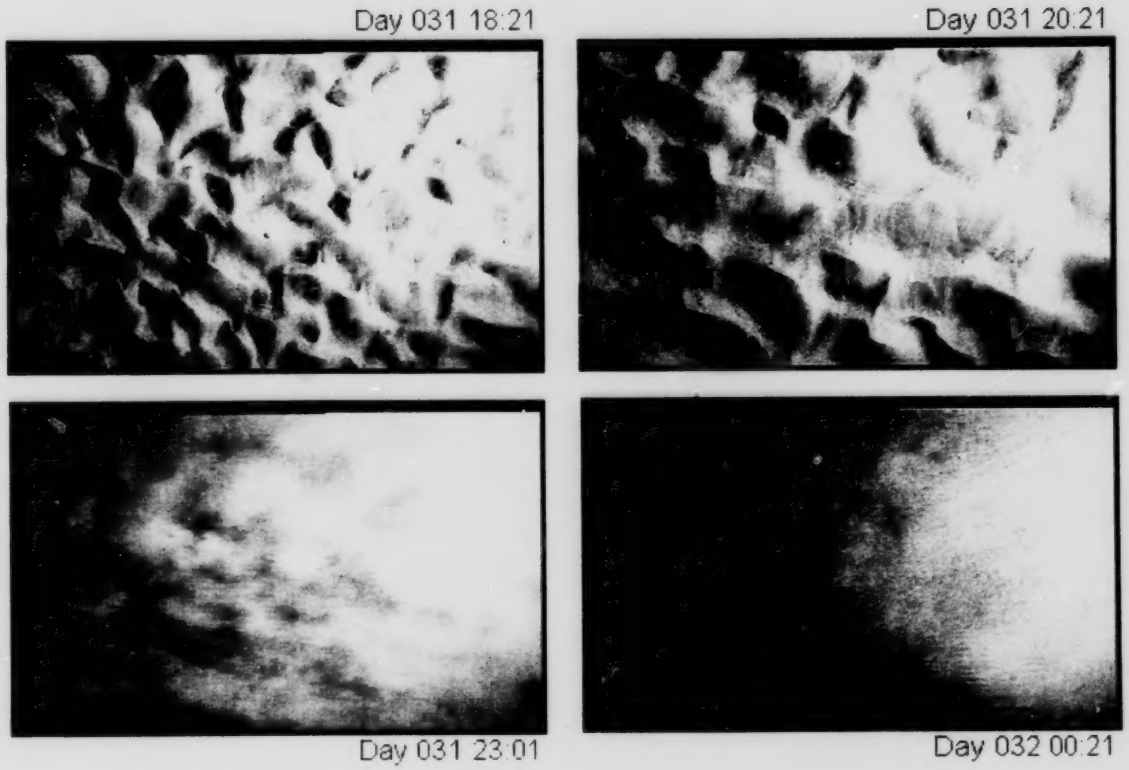

Figure 4: Seabed images in 32 m water depth collected in the RALPH 1997 January deployment on Sable Island Bank showing bedload transport over current ripples (18:21 and 20:21), sediment suspension over rippled bed (23:01) and sheetflow transport (00:21).

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RESEARCH ON THE FATES OF DRILLING WASTES

D. K. Muschenheim, *Acadia Centre for Estuarine Research, Acadia University*

Concerns over the potential deleterious effects of fine particulate drilling wastes prompted a study of the dispersal characteristics and fates of these materials on Sable Island Bank. Funding was provided by the Program on Energy Research and Development and the initial work was done at the Cohasset and Panuke (Copan) oilfields, lying approximately 45 km west of Sable Island in 38 m of water. The study provided an opportunity to apply new concepts and technology for the study of the near-seabed, or Benthic Boundary Layer, environment.

A combination of standard oceanographic and specialized sampling equipment was deployed at Copan from 1991 through 1997 during 10 research missions conducted from both DFO and industry vessels. Specialized gear developed and used during the course of this work included the following. The Benthic Organic Seston Sampler ("BOSS") is a tripod with a bank of spring-loaded 140cc syringes which are triggered simultaneously to provide a vertical profile of suspended sediment concentration and composition within 0.5 m of the seabed (Figure 5). The "Campod" is a large aluminum frame supporting Nikon still camera and Sony high-resolution video imaging equipment as well as the "Slurper" sampler for obtaining samples of flocculent material at the sediment-water interface. The Compact Aquatic Boundary Layer Explorer ("CABLE") was designed to be used by industry from ships of opportunity and supports water sampling (Niskin) bottles, optical backscatter sensors (OBS) and the digital silhouette camera for *in situ* imaging of suspended particulate matter (Figure 6). The Moored Impacts Monitoring System ("MIMS") is a large tripod, designed for long deployments on the seabed and is equipped with digital silhouette camera, current meters, OBS, transmissometer and altimeter.

A technique for analysis of the disaggregated particle size spectrum was applied to trace drilling wastes by the presence of the fine bentonite particles associated with "gel" muds. This was especially important at Copan as the wells were relatively shallow and drilling operations were done with a minimum of barite, the most commonly used drilling waste tracer. The initial trial comparing samples from within the discharge plume those taken in clear water demonstrated that the particle size analysis technique was sensitive enough to detect particulate drilling wastes. It also revealed that drilling waste fines accumulate in the benthic boundary layer. Subsequent studies at Copan delineated the extent of drilling waste coverage of the seabed, the fact that the waste particles flocculate, increasing their settling rate and that water column turbidity tends to increase with proximity to the platform.

A second study was initiated at the Hibernia field in 1995, when the baseline survey was completed, prior to emplacement of the Hibernia platform. The same equipment and techniques as were used at Copan also were applied to the Hibernia situation, with the addition of the Bottom-Referencing Unmanned Towed Instrumented Vehicle ("BRUTIV") for large-area imaging surveys of the seafloor. The first operational survey was conducted in October 1997 and resulted in the unexpected finding that drilling wastes were detected only in the upper water column. This result was reconciled by subsequent knowledge that drilling at that time was carried out with silicate-based muds, formulated with fresh water. Since Hibernia's switch to synthetic muds in early 1998, drilling muds have not been detected in the upper water column, but only slight amounts have since been detected in the benthic boundary layer. This may be due to differences in discharge practices, such

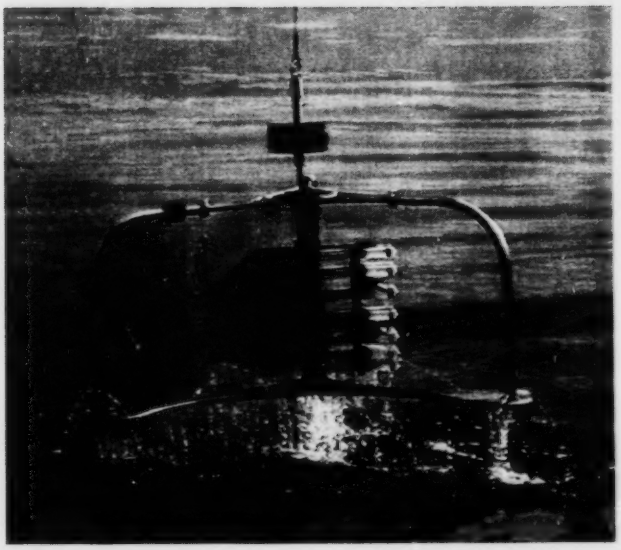

Figure 5: The Benthic Organic Seston Sampler (BOSS)

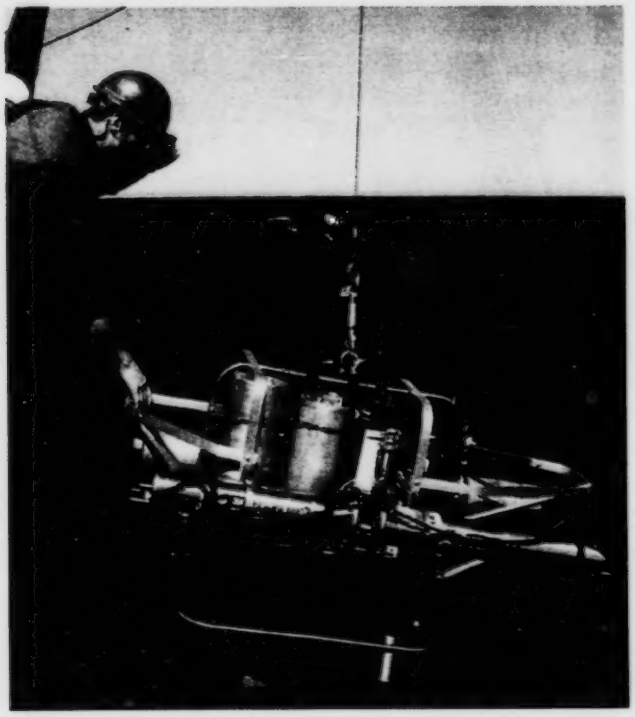

Figure 6: The Compact Aquatic Boundary-Layer Explorer (CABLE)

as pre-dilution with seawater.

Other datasets have been obtained on an opportunity basis, such as video and still camera seabed surveys at Terra Nova and the SOE Inc. sites, Venture, South Venture, Thebaud, North Triumph, Glenelg, and Alma. A transect from The Gully to the Venture site was first sampled, using Campod and CABLE, in 1998 and again in 1999. None of these datasets has as yet been analyzed.

This work has shown the efficacy of particle size analysis for the detection of particulate drilling wastes on energetic offshore banks, as well as the role of flocculation in retarding the dispersion of the fine fraction through increasing the settling rate. In addition to monitoring contaminant levels in seabed sediments, environmental effects monitoring programs should include sampling of the near-seabed region, as is currently being done in the SOE Inc. project. Future research in drilling waste fates should focus on methods of obtaining accurate *in situ* settling rates for particulate drilling wastes under a variety of conditions, to aid modelling efforts on particulate drilling waste dispersion.

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Posters

TOWARDS A GLACIAL AND POST-GLACIAL GEOLOGIC FRAMEWORK ON SABLE ISLAND BANK: A LONG-TERM HISTORY OF ENVIRONMENTAL CHANGE

Edward L. King, *Geological Survey of Canada Atlantic, Bedford Institute of Oceanography*

Development and monitoring of petroleum and other engineering ventures on Sable Island Bank requires some knowledge of the geologic processes or features which have a potential impact on the project. Investigations are necessarily site specific yet understanding of geologic conditions is usually enhanced when viewed in a regional context. However, this broader view can be difficult to ascertain. An enhanced regional geologic framework for the entire bank area is presently under development at GSCA. The deposits are mainly governed by the history of glaciations and sea level change so sediment types and distributions reflect these processes. Initial compilation involves a re-evaluation of a large shallow seismic database

collected by GSCA over the last 20 years. Ready access to this interpreted framework will be in the form of over 300 interpreted geologic sections (5500 line km), a suite of posting/contour maps of various surficial features and subsurface deposits, their thicknesses, and, where available, lithologies, geotechnical character and chronology. This information should be valuable for indicating surface and sub-surface conditions in planning stages for future site surveys and installations. The compilation will also contribute towards identification and depth/distribution maps of aspects or features considered potential geohazards. The framework will help place these features in a time/process context and thus aid in their understanding. Potential geohazards include sediment mobility (here, largely in an historical context), large and small scale buried channels with variable infilling sediment types, buried boulders, buried lag surfaces, buried clayey layers, enigmatic buried paleosurfaces with moderate relief, and shallow gas occurrences, now recognized in a variety of situations and locations.

The poster presents case studies and examples including glacigenic deposits at the North Triumph site, early post-glacial sediment transport trends, an improved regional sand ridge distribution map, details of apparent shoreline normal as well as shoreline parallel (or oblique) sediment mobility associated with the sand ridges just south of the island, examples of detailed regional geologic sections, and examples of shallow gas manifestations on seismic profiles.

CIRCULATION AND DISPERSION MODELLING ON THE ATLANTIC CANADIAN SHELF

Charles Hannah, Guoqi Han, John Loder, Zhigang Xu, Jennifer Shore and David Greenberg, *Fisheries and Oceans Canada, Bedford Institute of Oceanography*

Numerical circulation and dispersion models are being used with observational data to develop a quantitative representation of the physical environment on the Atlantic Canadian Shelf, with focus on offshore areas of active or potential hydrocarbon activities. Applications of relevance to hydrocarbon activities include descriptions and predictions of: spatial and temporal variability in currents, mixing, bottom stress, temperature and salinity; drilling waste drift and dispersion; suspended sediment transport; produced water drift and dispersion; and surface drift.

Finite-element circulation models forced by observational data are being used to obtain a 4-d representation of the seasonal, tidal and wind-driven currents on the shelf and upper slope between the Labrador Shelf and Georges Bank. Predicted currents are generally in very good agreement with observed currents on Georges Bank and the Western Scotian Shelf, and fair-to-good agreement with observed currents on the Eastern Scotian Shelf (including Sable Island Bank) and the Grand Banks. Pronounced influences of topography have been identified, including a predominant equatorward shelf-edge flow and partial gyres around offshore banks with seasonal variations, vertical structure in the response to wind forcing including an important (barotropic) component associated with surface elevation changes, and important inter-regional differences in tidal current magnitude and structure. Application of an inverse model to tides on the Southern Labrador and Newfoundland Shelves results in substantial improvement in current predictions on the Grand Bank. Detailed investigation of current structure and variability in the Sable-Banquereau-Gully region is currently underway (in collaboration with Coastal Ocean

Associates Inc.), using the circulation models, historical data and data recently collected by the hydrocarbon industry. Initial results indicate unusual complexity and variability in the tidal currents, apparently related to some combination of stratification, topography and friction.

The 4-d representation of currents from the circulation models can be used with parameterizations of turbulence influences to address various issues related to the drift and dispersion of materials released into the ocean. A primary area of focus has been the fate and concentration of drilling wastes or suspended sediment in the benthic boundary layer, for which a family of benthic boundary layer transport (bblt) models has been developed. In conjunction with observational and laboratory information on drilling waste properties and their effects on organisms, the circulation and bblt models provide a quantitative framework for assessing potential impacts of drilling wastes on benthic organisms for various discharge scenarios and physical settings. Information on the bblt models can be found in the Hannah et al abstract (oral presentation) elsewhere in this volume.

The model applications and development are part of an ongoing program funded by the Federal Panel for Energy, Research and Development (PERD) and the Department of Fisheries and Oceans. The finite-element models have been primarily developed by U.S. collaborators at Dartmouth College, and observational oceanographic data have been obtained from national archives and the offshore hydrocarbon industry.

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SUSPENDED MATERIAL ON SABLE ISLAND BANK

***Donald Belliveau**, Fisheries and Oceans Canada, Bedford Institute of Oceanography*

The Moored Instrument Monitoring System (MIMS) was developed at BIO as an instrument platform for the study of particulate drilling waste dispersion as well as being a prototype for a long-term deployment environmental monitoring tool. The MIMS frame is a large tripod supporting an instrumentation suite which has included current meters (both electromagnetic and acoustic) Optical Backscatter Sensor (OBS), transmissometer, pressure sensor, altimeter and the digital floc camera, which also was developed at BIO. MIMS is deployed on the seabed and has a self-contained recovery system so that no mooring tackle is exposed at the sea surface.

MIMS was deployed for a month in October, 1996, about 2 km from the jackup rig, Rowan Gorilla III, at the Cohasset field, Sable Island Bank. During the period from 9 October through 11 October a storm front passed through the region, generating significant wave heights of over 7 meters. Silhouette images from the digital floc camera, mounted 0.5 m above the seabed, during this period show the progression of suspended particle sizes with changes in the turbulent stresses in the water column. Initially little material is seen in suspension, with wave heights under 1 m. As the storm builds, first the flocculated material on the seabed is resuspended, then sheared into smaller particles and distributed throughout the water column. As wave heights reach 7m large amounts of sand are seen in suspension. As the storm passes, first the sand falls out of suspension then a dense concentration of flocculated material appears as the sheared flocs re-aggregate and settle rapidly in the more quiescent water column. Sixteen hours after the peak of the storm the flocculated material has re-settled and water column clarity is close to pre-storm levels.

The record provided by this MIMS deployment provides insight into the dynamics of sediment resuspension under storm conditions, as well as the effect of flocculation on settling rates of fine-grained particulate matter, such as drilling muds.

MULTISPECTRAL OPTICAL BACKSCATTER SIGNATURES OF SHELF WATER ON THE GRAND BANKS, OFF NEWFOUNDLAND

***Annamarie Hatcher, Paul Hill and Jon Grant**, Department of Oceanography, Dalhousie University*

There have been few measurements made of spectral backscatter in the ocean, because the technology has only recently been available. Our study was designed to measure spectral backscatter profiles in the waters of the Grand Banks at twenty eight stations around the Hibernia drilling platform. Sampling was conducted in June, 1998 during a regular sampling cruise by the Dept. of Fisheries and Oceans. Our aim was to track the early dispersion of fine inorganic particulates discharged during drilling operations by identifying changes in standard variables such as transmission, fluorescence, and OBS and identifying relationships among co-variates. Comparisons were made based on depth profiles within sites and among sites that vary in their proximity to discharge. Spectral backscatter profiles were made using the *Hydroscat-6* which measures the backscatter coefficients at six optical wavelengths. Backscatter coefficients indicated low concentrations of suspended particulate material at all sites at all depths. The shelf waters, with an average water depth of 77 m, were strongly stratified. Surface water temperatures

were approximately 6.0 ° C, and bottom water about 0.5 ° C with a pronounced thermocline at 25-30 m. A layer of high backscatter was identified at 62-67 m depth in proximity to the shale shute (station: HN0) which was caused by the release of drilling-waste particulates. At this site, the high backscatter was accompanied by low transmission (SeaBird transmissometer). Several diagnostic variables were identified that indicate the presence of drill waste particulates. These include high ratios of backscatter at 442 nm to transmittance at 660 nm and uncharacteristically flat spectral signatures of the backscatter coefficients. These relationships are significant for concentrations of drilling-waste particulates around 0.5 mg l^{-1} and higher, based on our laboratory investigations. Using diagnostic variables quantified during this research, we are now able to efficiently and comprehensively track early dispersion of drilling-waste plumes at low concentrations with real-time output.

SPECTRAL BACKSCATTER OF MARINE FLOCS COMPOSED OF DIATOMS AND DRILLING MUDS

Annamarie Hatcher, Paul Hill and Jon Grant, *Department of Oceanography, Dalhousie University*

In marine waters the majority of particulate material exists as flocs, which have optical characteristics different than the individual particles that compose them. Light scattering by flocs is extremely complex, with a twofold difference in attenuation expected simply due to the degree of flocculation. However, little is known about the spectral response of backscatter to flocculation. The present study was designed to explore the relationships between the backscatter coefficients at six optical wavelengths and the degree of maturation of flocs generated with a diatom culture (*Phaeodactylum tricornutum*) and a water-based-drilling mud used in the offshore oil industry. Flocs developed in a custom closed-system laboratory tank which was designed to gently suspend particulate material in an upwelling water current. As the flocs matured, changes in the properties of the suspended particulate material such as *in-situ* particle size distribution, chlorophyll content, and organic content were measured at regular intervals and compared to the backscatter coefficients at six optical wavelengths measured with a *Hydroscat-6*. Our preliminary results identify a drop in the red and green to blue ratios of the backscatter coefficients in the early stages of flocculation. The normalized spectral response of the backscatter coefficients of the flocs is distinctly different and much flatter than those of the two dominant components of the flocs, the diatom and the drilling mud. This research represents an early step in the evolution of economical optical monitoring of drilling-waste particulates after their release into the marine environment. The characterization of the spectral response of the backscatter coefficient is one of the keys to distinguishing aggregated drilling-waste particulates from naturally occurring particles. The optical fingerprints of the flocs which are formed when drilling-muds are released into the marine environment can eventually be used as a diagnostic either in an *in-situ* optical monitoring program or a monitoring program based on remotely-sensed ocean colour.

MULTI-PARAMETER MONITORING WITH A MOORED, WAVE-POWERED PROFILER

***Jim Hamilton**, Fisheries and Oceans Canada, Bedford Institute of Oceanography*

Comprehensive data provided by a moored, wave-powered profiler reveal changes over tidal to monthly periods in physical and biological properties in Bedford Basin. CTD, turbidity and chlorophyll profiles of ¼ m vertical resolution were collected in 70 m of water at 4 hour intervals over an 8 week period, using the SeaHorse profiler invented by Fowler (Fowler et al., 1997).

The SeaHorse profiler uses wave energy and a one-way clamp to climb down a mooring line. Once at the bottom it waits for a user-defined time when the clamp opens, and the buoyant device floats up the line while recording data from the on-board sensors. During the Bedford Basin deployment, there was sufficient wave activity to obtain full profiles 90% of the time.

The contour plots presented are produced from 317 profiles. The high profiling frequency and vertical resolution of the data, combined with the extended deployment period, provide a unique data set revealing features that would be difficult to capture using traditional sampling methods.

PARTICULATE DRILLING WASTES AT COHASSET AND PANUKE

***D.K. Muschenheim[1], T.G. Milligan[2], S. Armsworthy[2]**, [1]Acadia Centre for Estuarine Research, Acadia University and [2]Fisheries and Oceans Canada, Bedford Institute of Oceanography*

Introduction

A program to study the fates of discharged particulate drilling wastes (used muds and fine cuttings) was initiated with funding from the Program on Energy Research and Development (PERD) in 1993. This study built on preliminary sampling done in 1991, which showed that the drilling waste fines, previously thought to disperse rapidly, could accumulate in the benthic boundary layer just above the seabed. The PERD-funded study focussed on near- and far-field sampling around the jack-up rig Rowan Gorilla III, using standard oceanographic sampling gear and specialized samplers, such as the Benthic Organic Seston Sampler (BOSS). Data were collected during portions of eight research missions on DFO vessels as well as ship-of-opportunity sampling from rig supply and standby vessels.

Sampling at Panuke, 1991

Sampling for drilling waste residues was carried out from the standby vessel Ryan Leet in July of 1991. Samples were taken at fourteen stations, within 500 meters of the Rowan Gorilla III. A distinct surface plume from particulate discharges often was visible and CTD, Niskin bottle and BOSS samples were taken both directly inside and outside of the plume. Station 6 is an example of a station sampled outside of the discharge plume and shows a normal PSA signature for the Scotian Shelf. Station 5 was located within the discharge plume and clearly shows drilling waste signatures in the surface and benthic boundary layer samples but not in the mid water column.

Drilling Waste Detection by PSA

Typically, drilling wastes have been monitored through chemical analysis of barite and other constituents. Because the drilling operations at Cohasset/Panuke utilized very little barium, the Particle Dynamics Laboratory at BIO adapted its Particle Size Analysis (PSA) techniques to trace drilling wastes by the physical characteristics of the particle size spectrum. Bentonite, the major constituent in gel-based muds, has a characteristic size spectrum which can be used as a tracer

signature. Elevation of the spectrum at the fine particle end is a sign of contamination by drilling waste residues.

Video Survey of Flocculated Drilling Waste at Cohasset

The fine discharged drilling waste particles aggregate to form "flocs" which sink much faster that the individual particles would. This process contributes to the accumulation of drilling wastes either on the seafloor surface or in the benthic boundary layer. Most often these flocs contain significant amounts of naturally occurring organic matter, which may be enhanced by the discharge of produced water. In 1993 accumulations of flocs on the seafloor at Cohasset were monitored by a video survey which was designed to gauge the extent of coverage to the north and west (predominant flow directions) of the Rowan Gorilla III. Coverage was highest within 2 km of the rig, declining to near-background amounts by 3 km. Traces of drilling wastes were detected (by PSA) as far as 8 km away.

Transect Study at Cohasset

In 1996 a 20 km transect was sampled repeatedly from the supply vessel, Triumph Sea. The new Compact Aquatic Boundary Layer Explorer (CABLE) was utilized to provide bottom water samples, optical backscatter data and in situ floc imaging along the normal transit path of the vessel. The concentration of suspended particulate matter often increased with proximity to the rig, as did the diameter of the flocs. The greatest changes were detected in the lower portion of the water column. The example was taken during a period when there were no drilling discharges occurring but produced water was being discharged. The differences seen are due to higher rates of phytoplankton production close to the rig, probably enhanced by nutrients discharged in the produced water.

Summary

These panels represent only a portion of the PERD-funded studies done at the Cohasset and Panuke fields. This work has demonstrated the efficacy of using PSA for tracking particulate drilling wastes and the role that flocculation plays in transforming the fine drilling waste particles and enhancing their settling rate. In relatively quiet conditions drilling wastes combine with organic matter and can significantly impact the seafloor within 2-3 km of the source. The Rowan Gorilla III was often observed to be at the center of a large turbidity field caused by enhanced organic production near the rig, likely the result of nutrients provided in the produced water discharge. The results of this work provided information and data for the development of the "bblt" drilling waste transport model. Some of the techniques and equipment developed during the course of these studies have been subsequently adopted by industry for Environmental Effects Monitoring.

Acknowledgements

We thank the officers and crews of the DFO vessels *Parizeau* and *Hudson* and the Secunda Marine vessels *Ryan Leet* and *Triumph Sea.* Photography was provided by H. Wiele and P. Cranford. Sample analyses were performed by K. Saunders and A. Prior. Poster formatting and design elements were provided by A. Cosgrove.

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ESTER BASED DRILLING FLUIDS—STILL THE BEST ENVIRONMENTAL OPTION?

John Hall, *Baroid/Halliburton*

Invert phase (oil based) fluids have clear technological advantages over water based fluids. These include avoidance of the increased costs and atmospheric emissions due to longer drilling periods with WBM and increased fluid stability, promoting recycling of used fluids. Higher lubricity means greater well distances can be drilled, allowing fields that could not previously be exploited for economic or technical reasons to be exploited. Unfortunately, mineral oil based drilling fluids exhibit low biodegradability, higher toxicity and may contain toxic aromatic substances.

As an alternative to mineral oil based fluids, an ester based fluid was developed. This exhibits greater biodegradability, lower toxicity, and less potential to bioaccumulate, along with excellent technical properties. In many areas, regulators have given approval for this and other environmentally responsible fluids to be discharged on cuttings, while in many cases at the same time reducing the level of mineral oil based fluids on cuttings to a level where for practical reasons they cannot be discharged on cuttings.

This poster describes the original ester based fluid and compares it against mineral oils, and other synthetic based fluids in terms of biodegradation and toxicity.

FORMATION AND STRUCTURE OF OIL-MINERAL AGGREGATES IN COASTAL ENVIRONMENTS

K. Lee, P. Stoffyn-Egli, P. Wood, T. Lunel, *Fisheries and Oceans Canada, Institut Maurice Lamontagne*

Oil-mineral fine interactions have been identified as a significant process regulating the natural removal of stranded oil within coastal environments. To understand the significance of this process and its potential as an oil spill counter-measure (e.g. surf-washing), laboratory experiments were conducted to evaluate the ability of crude oils of different viscosity to form aggregates in seawater with common minerals (<5 μm grain size).

Two types of aggregate structures were observed: 1) "droplet": composed of one or more spherical oil droplets with mineral grains attached to their surface only; and 2) "solid": predominantly elongated forms composed of mineral particles mixed within the oil. The quantity of mineral in the aggregates controlled buoyancy.

The experimental data suggests that droplet aggregates will form with most oil and minerals

provided there is enough turbulence. Under these conditions, the oil is dispersed as discrete droplets which are then coated with mineral particles, and do not recoalesce. The predominance of "solid" aggregates with montmorillonite may be attributed to its ion exchange capacity, colloidal behaviour, and/or ability to absorb organic molecules within its expandable

THE EFFECT OF CLAY-OIL FLOCCULATION ON NATURAL OIL DEGRADATION

***A. M. Weise[1], K. Lee[2]**, Fisheries and Oceans Canada, [1]Bedford Institute of Oceanography and [2]Institut Maurice Lamontagne*

An interaction with fine mineral particles accelerates the removal and dispersion of stranded oil from spill impacted coastal regions. Shaker flask experiments under simulated environmental conditions were conducted to measure the significance of this intrinsic oil spill remediation process for the coastal marine environment. Results show that numerous crude and refined oil products produce stable micro-aggregates. Experiments conducted with a weathered crude oil over a 56-day period (10 °C) indicated that oil-mineral fine interactions stimulated bacterial growth and the rate and extent of hydrocarbon degradation. At the end of the experimental period, only 25% compared to 48% of the *n*-alkane fraction (n-C_{15} to n-C_{35}) remained in flasks treated with and without mineral fines, respectively. Similarly, the percent total target aromatics remaining was substantially lower in mineral fine amended samples (8%) than in oiled controls (25%). These results support the application of shoreline clean-up techniques based on the acceleration of oil-mineral fine interactions.

SHORELINE CLEAN-UP BY ACCELERATION OF CLAY-OIL FLOCCULATION PROCESS

***K. Lee, P. Stoffyn-Egli, T. Lunel, P. Wood**, Fisheries and Oceans Canada, Institut Maurice Lamontagne*

On February 15, 1996, the *Sea Empress* ran aground near Milford Haven (U.K.), spilling 72 000 tons of Forties Blend crude oil. During the clean-up operations it was observed that the oil emulsion did not adhere strongly to the shoreline and that fine mineral particles present in the surf waters interacted with oil to form clay-oil flocs. In an attempt to enhance clay-oil flocculation, Amroth beach was subjected to repeated "surf washing": the oiled cobbles from the high water mark were moved down to the intertidal zone using an excavator at low tide. After four days of treatment, most of the oil emulsion was removed from the cobbles. Microscopical and chemical analysis of samples of flocs and oiled sediments showed that energy imparted to the surf zone resulted in clay-oil flocculation and enhanced biodegradation of the oil.

Surf washing increased the availability of fine mineral particles which 1) minimized the contact of oil directly with the substrate, thereby reducing the adhesion of oil to the shoreline and 2) prevented the re-coalescence of oil droplets, thereby promoting the dispersion of oil within the surf zone.

ACCELERATING THE NATURAL RECOVERY OF OIL SPILL IMPACTED SHORELINES

***K. Lee, P. Stoffyn-Egli, R. Prince, G. Sergy**, Fisheries and Oceans Canada, Institut Maurice Lamontagne*

The In-situ Treatment of Oiled Sediment Shorelines (ITOSS) Program was designed to validate, on an operational scale, new techniques to enhance the natural recovery rates of oiled shorelines. For this purpose, representative beaches similar to those found in the Canadian Arctic, were oiled on Svalbard Island, Norway, in August 1997. One week after the oil was applied, the experimental beach plots were subjected to treatments including fertilization and sediment relocation.

Within two weeks, microbial respiration (CO_2 production) in the sediment, was significantly enhanced in the fertilized and tilled-fertilized plots as compared to the untreated control plots.

Sediment relocation, which promoted the formation of oil-mineral aggregates, effectively removed oil stranded within the beach. This oil dispersed into the sea and was rapidly degraded by naturally occurring bacteria.

Both bioremediation (enhanced biodegradation by nutrient enrichment) and sediment relocation (surf-washing and / or tilling) were effective in accelerating natural oiled shoreline recovery processes. The experimental treatments did not increase toxicity within the sediment or surrounding waters. Oil dispersed in seawater was biodegraded rapidly by natural bacteria present in the sea.

Bioremediation and sediment relocation are beneficial because they promote natural recovery and reduce toxicity without adverse environmental side-effects, and they are simpler and less expensive to carry out than current oil spill countermeasures proposed for use in remote areas such as the Arctic.

BACKGROUND OF POLYCYCLIC AROMATIC HYDROCARBONS IN INVERTEBRATES: BLACK DUCK COVE, 30 YEARS AFTER A BUNKER C FUEL OIL SPILL.

***J. Hellou[1], C. Anstey[1], T. King[1], J. Leonard[1], S. Steller[1] and K. Lee[2]**, Fisheries and Oceans Canada, [1]Bedford Institute of Oceanography, and [2]Institut Maurice Lamontagne*

Three species of invertebrates were collected from Black Duck Cove, Nova Scotia, to investigate the level of polycyclic aromatic hydrocarbons in animals repopulating a beach that received part of a spill of Bunker C fuel oil, 30 years ago. The brown or common periwinkles, *Littorina littorea*, the amphipods, *Gammarus oceanicus* and the soft shelled clams, *Mya areneria* are abundant in the three micro environments of that beach. At each of the sites, periwinkles displayed the highest PAH concentrations (wet weight), while concentrations in amphipods were relatively similar to clams. However, periwinkles also displayed five times lower moisture content than the other two species, explaining some of the observed differences. Examining results by species and site, concentrations in periwinkles did not vary by location; in the case of amphipods, concentrations were higher at the rocky more inshore site; while they were lowest at that same site for clams. As expected, the bioavailability of PAHs differed with species due to their preferred habitat and feeding habits. Generally speaking, background levels of combustion PAHs were observed with a possibility of traces of Bunker C fuel oil observed in clams.

ENVIRONMENTAL AND BASELINE ASSESSMENT OF POLYCYCLIC AROMATIC HYDROCARBONS LEVELS IN TRINITY BAY, NEWFOUNDLAND: SOURCE IDENTIFICATION THROUGH MOLECULAR AND CARBON ISOTOPIC FINGERPRINTING

***R. Helleur**, Memorial University of Newfoundland*

As part of Memorial University three year Eco-research project, "Sustainability in a Cold Ocean Coastal Environment", a group of marine chemists undertook an extensive marine field program to study both natural and anthropogenic influences on the marine ecosystem of Trinity Bay. A major focus was on the cycling of organic matter and pollutants in the water column and marine sediment. One field study involved the measurement and characterization of hydrocarbons.

Communities along the coast of Newfoundland are concerned about the potential impact of offshore oil development and environmental consequences of oil spillage. It is therefore prudent that our marine hydrocarbon study of a coastal ecosystem be viewed as a good baseline assessment of anthropogenic hydrocarbons. In addition to measuring their abundance and chemical nature ("Molecular Fingerprinting"), carbon isotopic characterization of individual hydrocarbons, ("Isotopic Fingerprinting") was used as a complementary techniques in determining the source of contaminants.

The toxic and carcinogenic characteristics of polycyclic aromatic hydrocarbons (PAH) has generated great interest in tracing the origin of these compounds deposited in sediments. Past studies have relied on the molecular fingerprint for discriminating between natural and anthropogenic and among anthropogenic PAH sources. However, physical, chemical and biological weathering reactions on PAH have created limits to source assignments. Previous studies have shown that the isotopic signature of PAH are not significantly altered when exposed to weathering reactions. Therefore, isotopic along with molecular fingerprinting of individual compounds have a good potential to be used as robust indicators or tracers of PAH (and other pollutants such as drilling oils) in sediments (and possibly marine biota).

Moderately polar to non polar lipid fraction of marine sediments were soxhlet-extracted , the hydrocarbon component cleaned up on an alumina column followed by fractionation on a silica column into two distinct fractions 1) aliphatic and 2) aromatic (includes the PAH). Isotopic fingerprinting of parental PAH was preformed by compound-specific isotopic ratio mass spectrometry (located in the Dept. of Earth Science). Molecular fingerprinting of parental PAH was conducted using a HP GC-MSD (SIM mode). Deuterium–labeled PAH were used as internal standards for quantification.

Excellent baseline measurements of sediment PAH for coastal marine environment have been secured. Levels of PAH (50-250 ng per g (dry weight) are generally low. Significant elevation of PAH was observed near small watershed outflows. Evidence from isotopic fingerprinting (isotopically ^{13}C heavier PAH than that of petrogenic PAH) strongly suggest that the major source of sedimentary PAH is from wood burning (i.e., atmospheric deposition of chimney soot followed by particle transport to the sediment). The molecular fingerprint supports this conclusion where fluoranthene/ pyrene ratios are >1 and where there was higher abundance of the less-stable/ kinetic isomers which are suggested of indicating combustion sources.

Presentations

DETECTING CHANGES IN THE EASTERN SCOTIAN SHELF ECOSYSTEM — WHAT CHANGE AND WHY?

Kees Zwanenburg, Fisheries and Oceans Canada, Bedford Institute of Oceanography

Over the past 30 years DFO has carried out trawl surveys of the Scotian shelf that allow us to track changes in the species and size composition of fish communities and to track changes in the physical environment. Bottom temperatures on the eastern Scotian shelf got very cold during the late 1980's and have remained cold until very recently. During this cold period the eastern shelf was invaded and in some cases colonized by a number of cold-water fish and shellfish species like capelin, turbot, northern shrimp, and snow crabs. During warmer periods these species are all more prevalent in the colder waters of the Gulf of St. Lawrence or the Grand Banks to the north. Some scientists argue that the reduced numbers of cod and other predators (which feed on these species) also contributed to the increase of these populations.

Since the 1970s average weights of commercially targeted demersal fish decreased by 51% on the eastern shelf and by 41% on the western shelf. For both systems the integrated community size frequency showed long-term declines in proportions of large fish, and trawlable biomass of most targeted species is presently at or near the lowest observed. In the east these changes coincided with a doubling of fishing effort, and a decline in bottom temperature to the lowest in 50 years. In the west fishing effort more than doubled while bottom temperatures reached the highest in 50 years. In both systems declines in biomass and average weight were more prevalent for commercially targeted species than for non-target species.

Since the closure of the cod fishery on the eastern shelf in 1993 and the restrictions on landings on the western shelf, average weights and the integrated community size structure have stabilized. In the east this stability is associated with increasing bottom temperatures and reduced effort while in the west it is concurrent with reduced landings and high bottom temperatures.

We conclude that both fishing and changes in bottom temperature have influenced demersal fish size but that the relative effects cannot be determined from current observations (Figure 7). The annual sampling rate on Sable Island Bank, with an area of about 3000 nm^2, has been about 15 trawl sets per year. This means that each trawl set represents about 200 nm^2, near the average for the entire Scotian Shelf. With this sampling rate, which was designed to monitor large-scale changes in abundance and distribution on a shelf-wide basis, and the variability introduced by climatic changes, it seems unlikely that these surveys will be able to detect changes resulting from local effects of oil and gas production. In addition, primary and secondary productivity, benthic productivity, and pelagic fish production are not monitored, making it even less likely that oil and gas related changes would be detectable by the present monitoring system. It was concluded that high (spatial and temporal) resolution surveys of at least fish and benthic invertebrates are a necessary pre-requisite to detect changes related to oil and gas exploration of Sable Island Bank.

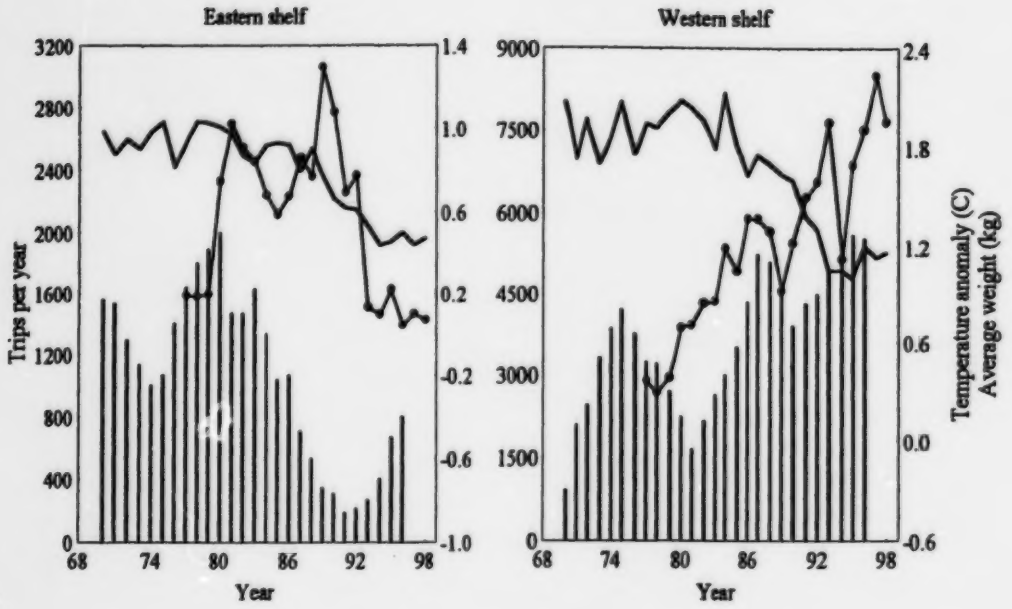

Figure 7: Trends in bottom temperature anomalies (5 year running mean anomaly from an average calculated since 1960, bars), fishing effort (circled line), and average weight of commercially targeted species (heavy solid line) for the eastern and western Scotian Shelf. These results indicate that changes in fish populations, such as the change in average weight observed here, take place against a variable environmental background. Determining the relative effects of human activities (such as fishing effort) and environmental change, is difficult. Tracking potential effects of human activities on smaller portions of the Scotian Shelf , such as drilling and extraction operations on Sable Island Bank, require intensive long-terms sampling and sound baseline information.

ASSESSING IMPACTS OF OIL DEVELOPMENT ON THE GRAND BANKS OF NEWFOUNDLAND

***Jerry Payne**, Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre*

The offshore oil and gas industry which is rapidly developing on the Grand Banks of Newfoundland has become a focus of concern for potential effects on fisheries and the environment. The Terra Nova, Hibernia and White Rose Fields are situated on important fishing grounds in a relatively small triangle on the North East edge of the Banks. The potential for cumulative impacts in the area from discharges of drilling muds, production waters and displacement waters over the next few decades will likely be an ongoing concern.

What will be the scale and nature of impacts at individual sites? There is a substantial body of knowledge from field studies in the North Sea, Gulf of Mexico and California. There are companion laboratory studies with petroleum hydrocarbons, drilling fluids and production waters, areas that we have also researched through support from the Program on Energy Research and Development. The majority of information available suggests that offshore impacts will be minimal. Overall inputs of hydrocarbons and metals will also be extremely low in comparison

with inputs from natural and other anthropogenic sources. Also, unlike high level inputs of hydrocarbons and metals into point sources in coastal waters from rivers (naturally), sewage, shipping and urban runoff, inputs in the offshore will be subjected to rapid dilution.

However general statements should always be tempered with caution. Uncertainties and controversies regarding the seriousness of potential effects of oil development still exist, particularly with regard to chronic effects. For instance, although some synthetic drilling fluids are similar in composition to formulations used in pharmaceuticals, cosmetics and emollients (for which there is a large data base with respect to human toxicity), it is important to carry out chronic toxicity studies with selected marine organisms. This is quite important, if only for assurance, in relation to potential for effects on such rich fishing grounds as the Grand Banks. Also, with respect to production waters (or displacement waters), although none of the (many) studies to date have demonstrated potential for acute effects on larvae, plankton etc. beyond immediate dilution zones, some chronic toxicity studies of a dose-response nature are warranted, again if only for purpose of assurance. These studies should cover aspects related to potential for localized changes in structure of plankton communities (eg. especially in relation to any major "stagnant" water lens effects) and fish larval toxicity as well as adverse effects on long-lived organisms, either of commercial importance or important in fish productivity.

Given the juxtaposition of the fishing and oil industries on the Grand Banks, the monitoring program should place emphasis on determining the nature and extent of any adverse impacts on fish and the fishing industry (eg. effects on fish health as well as real or perceptual concerns about tainting and contamination) as well as more general environmental concerns. This might seem to be common sense but most studies in the North Sea have placed emphasis on investigations of zones of impact on soft bottom communities in relation to the debate over use of oil versus water based drilling fluids. This is an important issue in relation to degree of habitat loss/alteration (which is generally indicated to be minimal) but far field effects that might impact fish and the fishing industry should be a key aspect for monitoring programs to address in relation to oil development on the Grand Banks. Recent studies on MFO enzyme levels in adult and larval fish in the North Sea, particularly in the area of the East Shetland Basin, as well as our chronic toxicity studies with fish and recent PERD supported studies on American plaice around the Hibernia Site, reinforce this need. Terra Nova has already incorporated fish health measures (MFO and histopathology) in their monitoring program. Similar fish health measures have also been carried out in conjunction with the start-up of the Newfoundland Transshipment Terminal in Placentia Bay.

Why use health indicators such as fish histopathology? Chemical monitoring of fish is inadequate as a measure of fish health since many chemicals, including heavy metals and hydrocarbons, may not accumulate in fish tissues to any degree yet be quite damaging (so-called "hit and run" phenomenon). Also, since there are few studies linking body burdens to health effects, knowing the concentration of a chemical in an animal does not necessarily provide sufficient evidence for determining effects.

The purpose of using fish histopathology is to provide an early warning and screening type of measure for problem identification of potential impacts on fish. The logic underlying such an approach is that for population level effects or higher to occur, the first level of interaction with the chemical(s) has to be at the individual level. It is also realized that cause and effect relationships between chemical contamination and observed changes at the population or community level can

be quite difficult or impossible to establish (for practical as well as theoretical reasons). Furthermore, population level changes may take years to be realized, and be difficult to "reverse". It is also understood that identification of severe health effects in fish is in itself important to know, even if same cannot be translated into for instance, a 10%, 20% etc. population loss.

Histopathology which "integrates" across all classes of chemicals (PAH, metals etc.) has traditionally been a pillar of human and veterinary medicine and is proposed to be one of the most reliable indicators for serious health impairment by aquatic chemicals. Agencies such as ICES recommend fish histopathology as a key monitoring/assessment tool and the North Sea Action Plan under the aegis of the Oslo Paris Commission, has endorsed use of fish histopathology.

The use of individual level effects can be a owerful tool for "disproving" as well as "proving" the deleterious effects of chemicals. For instance, perceptions/concerns about population level effects stemming from direct toxicity would have little scientific credibility in the absence of evidence for individual level effects.

In conclusion, oil development on the Grand Banks appears to pose little risk to fisheries and the environment. However, there are important knowledge gaps with respect to chronic ecotoxicological effects that need to be addressed for reasons of reducing uncertainty. The "final" step in addressing uncertainty is to have in place rigorous monitoring programs which will provide early warning of any adverse impacts on fish, fish larvae and plankton as well as soft bottom sediment communities. Monitoring for potential contamination and tainting problems with respect to fisheries resources should also be a very high priority, with focus on actual resource species in question, not surrogates.

BIOLOGICAL EFFECTS OF DRILLING WASTES

***Peter J. Cranford**, Fisheries and Oceans Canada, Bedford Institute of Oceanography*

Decisions about the development of energy resources must integrate economic, environmental and social issues. Based on the economic reality that a sustainable commercial fishery must coexist with the offshore petroleum industry, comprehensive studies are needed to identify and minimise the impact of operational drilling wastes on sustainable fishery resources. A viewpoint commonly held until recently was that impacts on commercial fish and shellfish should be restricted to the immediate vicinity of production drilling platforms. However, laboratory and field observations indicate impacts on fisheries at much greater distances than originally envisaged. The rapid escalation of offshore oil and gas production on the eastern Canadian continental shelf has resulted in an urgent need to collect direct scientific information on the environmental consequences of these developments. The Department of Fisheries and Oceans, primarily through funding from the Panel for Energy Research and Development (PERD), has been conducting research on the biological effects of drilling wastes since the late 1980's.

One of the most important environmental concerns related to the impact of offshore oil and gas developments is the consequence to resident organisms of long-term exposure to low-level

contaminants. Studies on the chronic lethal and sublethal biological effects of production drilling wastes have, and continue to be, conducted under environmentally relevant conditions to assess the biological effects of particulate wastes generated from the use of existing and new production drilling technologies. The sea scallop *Placopecten magellanicus* has been the primary target species used in this work as they are an important and widely distributed offshore resource species, the bulk of particulate drilling waste discharges rapidly reaches and concentrates on and near the seabed, and they are sedentary and unable to escape chronic exposure. Our research has shown scallops to be highly sensitive to impacts from drilling wastes, such that they are an effective sentinel species. Results from long-term chronic effects studies in which sea scallops were exposed to a variety of used drilling fluids and major components are being used to assist regulatory agencies and industrial interests in developing scientifically sound and justifiable regulations. In this regard, an example is the recent controversy surrounding the use of water- and oil- verses synthetic-based drilling muds.

The actual risk to the sustainability of resource species is being assessed by integrating laboratory toxicity data with information on the distribution and transport of drilling wastes in the environment, collected as part of the multidisciplinary PERD program. Environmental concerns identified based on the results of laboratory biotests and risk assessment modeling have led to the development of practical, sensitive, and cost-effective technologies and methodologies that use resident resource species to detect and monitor environmental impacts at offshore production sites. These can be used to identify the spatial extent of population effects and to assess the cumulative effect of waste discharges from different sources. Collectively, these studies were designed to provide sound scientific information and technologies that can form a basis for informed management decisions and the formulation of environmentally responsible drilling practice regulations and environmental monitoring standards for offshore oil and gas developments.

Figure 8: Raceway facilities for assessing the chronic toxicity of suspended drilling wastes.

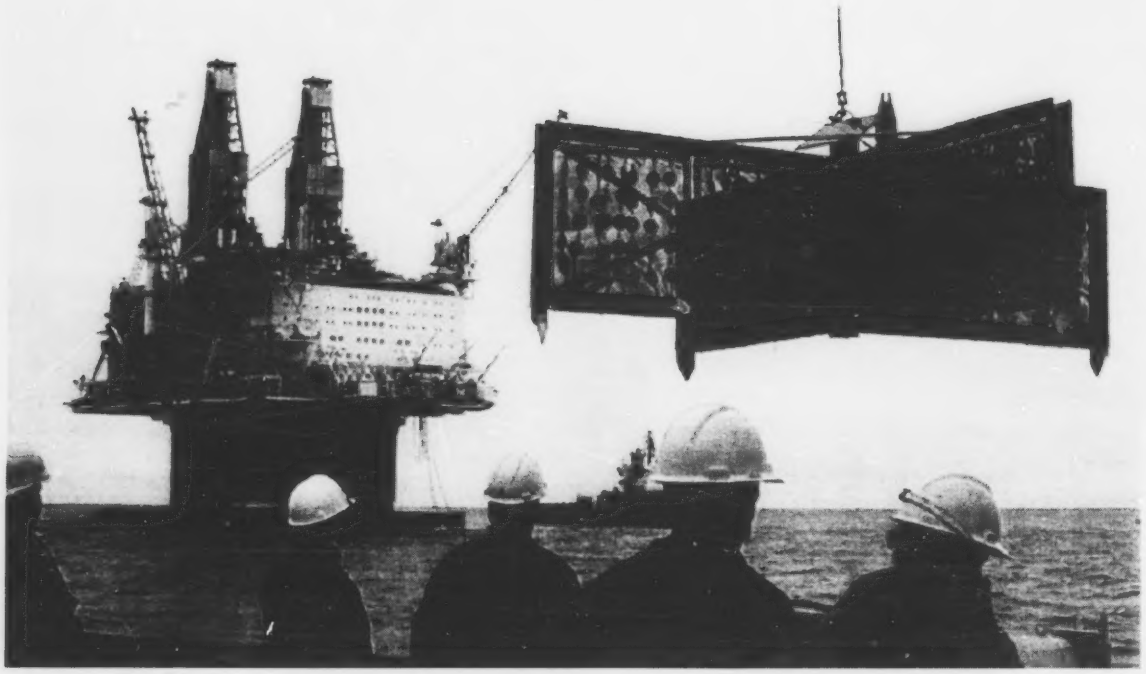

Figure 9: Recovery of caged shellfish mooring at Hibernia. Icelandic and sea scallops and mussels are used to measure contaminant distribution and biological effects.

ENVIRONMENTAL ASSESSMENT OF POTENTIAL PRODUCED WATER IMPACTS AND DEVELOPMENTS IN OIL SPILL COUNTERMEASURES

***Kenneth Lee**, Fisheries and Oceans Canada, Institut Maurice Lamontagne*

Produced Water

With the development of Canada's offshore oil and gas reserves, large volumes of produced water may be discharged into the ocean. The formation-water components of production waters are, in effect, brines that derive their salinity from the major ions found in seawater. However, depending on the nature of the formation from which they are withdrawn, they may contain a number of metal and organic constituents of environmental concern including: 1) hydrolysis metals, 2) heavy metals, 3) petroleum hydrocarbons, 4) nutrients, 5) radionuclides, and 6) treating chemicals.

While acute toxicological effects of production water discharges may be reduced to acceptable regulatory limits by dilution within a short distance from the point of release, there is some evidence from the North Sea that long-term ecosystem effects may be induced by low-level exposures. Furthermore, preliminary studies at the Cohasset site have demonstrated that produced water discharges will induce flocculation processes that mediate the concentration and transport of contaminants to the benthic environment and the sea-surface microlayer. Based on the economic reality that the sites of our commercial fisheries must coexist with the offshore industry, Fisheries and Oceans has initiated a comprehensive multi-year study to assess the potential impact of produced water discharges. Since the composition of produced water from different sources and

formations can vary by orders of magnitude on a constituent-specific basis, a regional study on production water impacts in Atlantic Canada is necessary. This research program will address: 1) the chemical characteristics of the produced water, 2) the significance of flocculation processes in the transport of produced water contaminants, 3) the potential impacts of produced water to marine biota, 4) methods to identify and trace the impact zone of discharges, and 5) the application of numerical models to predict the fate and effects of wastes from offshore hydrocarbon platforms. The final ecological risk assessment will include recommendations for changes in regulatory guidelines and environmental monitoring protocols to ensure safe disposal of produced waters in the marine environment.

Development of Oil Spill Countermeasures

Microbial degradation is a principal process in the elimination of petroleum contaminants from the environment. Bacteria and fungi with the capacity to degrade a wide range of oil components exist throughout the marine ecosystem. The natural rates of hydrocarbon biodegradation are usually limited by abiotic environmental factors. Nevertheless, as demonstrated at a site impacted by a spill of Bunker C oil in 1970 from the grounding of the tanker *Arrow* in Nova Scotia, given sufficient time a significant fraction of petroleum hydrocarbons will be degraded. In consideration of this fact, PERD has supported an ongoing DFO research program to develop and validate *in situ* bioremediation techniques. Controlled field trials (including Scotian Shelf condensate, Hibernia and Terra Nova crude oils) and demonstrations following spill incidents (e.g. Exxon Valdez, Sea Empress) have shown bioremediation to be a promising oil spill countermeasure. Treatment strategies have included bioaugmentation (e.g. seeding) involving the addition of oil-degrading bacteria; and biostimulation, (e.g. nutrient/oxygen amendments, phytoremediation, surf-washing) involving the addition of nutrients or growth enhancing co-substrates and/or improvements in habitat quality to stimulate the growth of indigenous oil degraders. Future research is focused on identifying the benefits and limitations of bioremediation relative to existing technologies, and to providing guidance for its application. Operational guidelines under development will include protocols for testing and selection of bioremediation agents and standard toxicity test methods for efficacy monitoring and operational endpoints.

Posters

DISTRIBUTION OF A RESTRICTED RANGE OF POLYCYCLIC AROMATIC COMPOUNDS IN TISSUES OF FINFISH

J. Hellou, J. Leonard and C. Anstey, *Fisheries and Oceans Canada, Bedford Institute of Oceanography*

Rainbow trout were exposed orally, over a period of four months, to four polycyclic aromatic compounds (PACs). The experiment mimicked the level of contaminants that could be introduced in food available to fish living near a spill site. Four compounds were chosen according to their physical-chemical properties; to their similarity to some abundant PACs present in light oils and creosote; and because of the scarcity of data regarding the fate of nitrogen, oxygen and sulfur substituted aromatic compounds. These PACs are fluorene, carbazole, dibenzofuran and dibenzothiophene. The bioaccumulation, bioelimination and/or biotransformation of the

PACs were investigated in several tissues, i.e. muscle, liver, internal organs, fatty tissue, as well as blood, bile and faeces. Results were examined on an organ and weight basis, in terms of water as well as lipid content, to compare bioavailability. Results examined on a monthly basis indicate more similarity between the distribution of compounds after the four months, than in the short term. Examining tissues, muscle and internal organs displayed the highest load of contaminants, while fatty tissue showed an intermediate load, and liver and blood contained relatively less material. Non reacted PACs were eliminated through the faeces, while glucuronide conjugates were eliminated through the gall bladder bile. Results need follow up.

EFFECT OF DRILLING FLUID ON ENZYMES INVOLVED IN METABOLISM OF CHEMICALS

Hui Wang[1], Jerry F. Payne[2] and Anver D. Rahimtula[1], *[1]Memorial University of Newfoundland and [2]Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre*

Drilling fluids are used extensively as lubricants by the oil and gas extraction industry. One commonly used drilling fluid is IPAR, a synthetic product consisting of linear, cyclic and branched chain hydrocarbons. It is essentially free of polar sulfur, nitrogen and oxygen compounds as well as polycyclic aromatic hydrocarbons and has very low toxicity. However, there is concern about the subtle non-lethal effects of these fluids on fish in the vicinity of offshore drilling sites. Here we have examined the effects of administration of the drilling fluids IPAR and NEODENE to rats on some hepatic and renal phase I, phase II and ß-oxidation activities.

Our results show that both IPAR and NEODENE are relatively non-toxic to rats with no overt adverse effects seen over a 12 day period after as many as 4 i.p. doses. However, both IPAR and NEODENE produced a number of metabolic alterations although their effects were quite different. Thus, NEODENE consistently decreased total hepatic cytochrome P450 levels as well as lauric acid hydroxylase (P4504A1-dependent), ethoxyresorufin O-deethylase (P4501A1-dependent) and glutathione S-transferase (DCNB as substrate) activities. Pentoxyresorufin O-dependentylase (P4502B1-dependent) activity remained unaltered. In contrast, IPAR elevated total hepatic P450 levels as well as ethoxyresorufin O deethylase and glutathione S-transferase activities. Pentoxyresorufin O-dependentylase activity was very substantially elevated. Neither fluid had much effect on carnitine acetyl transferase activity although both elevated palmitoyl CoA oxidase activity but only after 4 doses. Our results show that both NEODENE and IPAR have the potential to cause metabolic dysfunction in rats at high doses. These fundamental biochemical studies support the hypothesis of little or no direct toxicity at petroleum development sites in the offshore.

TOXICITY OF PRODUCED WATER TO THE EARLY LIFE STAGES OF HADDOCK, AMERICAN LOBSTER AND SEA SCALLOP

K. Querbach[1], G. Maillet[2], P. Cranford[1], C. Taggart[2], K. Lee[1], and J. Grant[2] *,[1]Fisheries and Oceans Canada, Bedford Institute of Oceanography and [2]Department of Oceanography, Dalhousie University*

Acute and chronic of exposure to produced water (PW) from an offshore oil production facility were quantified for the early life stages of haddock (*Melanogrammus aeglefinus*), lobster (*Homarus americanus*) and sea scallop (*Placopecten magellanicus*) in terms of survival, growth and fertilization success. During 96-h exposures to 0-25% PW, yolk-sac haddock larvae, fed stage-I lobster larvae, and scallop veligers each displayed significant reductions in survival at 10 and 25%. The average size of scallop veligers was significantly reduced after exposure to 10 and 25% PW. Scallop fertilization success was significantly reduced at all concentrations ≥ 1%. During 18 d chronic exposures to concentrations of 0-10% PW, significant reductions in scallop veliger survival and size were observed in the 10% treatment. Chronic exposure of the diatom, *Thalassiosira pseudonana*, to 10% PW resulted in a significant reduction in physiological condition though there was no effect on chlorophyll-*a* concentration.

Significant ($P < 0.05$) acute effects of PW on scallop fertilization and the larval stages of haddock, lobster and scallops were detected at concentrations between 1 and 10%. As PW rapidly dilutes to concentrations below these levels, acute impacts should be limited to the vicinity of the discharge. However, precipitation or adsorption of PW contaminants onto particles increases the risk of impacts. Although scallop veligers were relatively insensitive to impacts from chronic exposure to low levels of PW, it is possible that effects may be manifested later in life. Indirect effects of PW on larvae may also result from subtle effects on other ecosystem components (e.g. microalgae productivity). This study has shown the potential for using resource species in toxicological evaluations rather than 'classical' lab species that may not be representative of communities near offshore oil and gas production fields.

CHRONIC TOXICITY OF SYNTHETIC OIL-BASED DRILLING MUD TO SEA SCALLOPS

Peter J. Cranford, Shelley Armsworthy, and Kirsten Querbach*, Fisheries and Oceans Canada, Bedford Institute of Oceanography*

An important environmental concern related to offshore oil and gas production is the consequence to resident marine organisms of long-term exposure to low-levels of drilling wastes. Drilling fluids containing synthetic oils, which have a low aromatic hydrocarbon content, were developed in response to observations of the high chronic toxicity and benthic community impacts associated with the discharge of diesel- and mineral oil-based drilling muds. Synthetic oil-based mud (SBM) is currently in use for oil and gas production drilling on the Scotian Shelf and the Grand Banks, however, little is known of the chronic toxicity to resource species of these new drilling fluids. Sea scallops (*Placopecten magellanicus*) were exposed in the laboratory for approximately two months, and at different times of the year, to different types and concentrations of used synthetic oil-based drilling muds (SBM). Experiments were conducted in recirculating

raceway tanks that maintain the drilling mud in suspension around scallops. Toxicity was assessed from chronic mortalities, somatic and reproductive tissue growth and physiological condition.

Sea scallop survivorship in SBM treatments (0.07 to 9.6 mg L^{-1}) during summer and winter exposures to SBM was similar to the control. The Novaplus and IPAR 3 SBMs had a similar impact on scallop tissue growth, which was significantly reduced at 0.07 (winter) and 1.0 mg SBM L^{-1} (summer). Growth impacts from SBM resulted primarily from reduced energy intake through feeding (clearance) and digestion (absorption), but increased energy losses to respiration and excretion also contributed to reduced growth. Scallop clearance rate was particularly sensitive to the presence of suspended SBM and an EC_{50} value between 0.2 and 0.5 mg L^{-1} was indicated. The toxicity of the used SBMs tested was relatively low compared with drilling fluids containing low-toxicity mineral oil. However, SBM continues to be an environmental concern as growth, reproductive development and nutrient storage in adductor and digestive gland are all reduced at environmentally relevant concentrations. These responses can result in population level impacts if a significant proportion of the stock is exposed.

THE RESPONSE OF *SCIRPUS PUNGENS* TO CRUDE OIL-CONTAMINATED SEDIMENTS

***[1]D. Longpre, [2]K. Lee, [1]V. Jarry**, Fisheries and Oceans Canada, [1]Bedford Institute of Oceanography and [2]Institut Maurice Lamontagne*

The wetland plant *Scirpus pungens* is commonly found along the shores of the St. Lawrence River. This plant is of ecological importance as it provides a unique habitat for a diverse number of biota and is essential for the control of coastal erosion. The potential impact of an accidental oil spill on wetlands dominated by this species is unknown. To partially resolve this question, *Scirpus pungens* and sediments were recovered from a site near Ste. Croix, Quebec, for an exposure study using medium-light crude oil contaminated sediments.

Transplants in oiled (range: 1.14 - 72.9 g/kg) and unoiled (control) sediments were maintained in a greenhouse facility to monitor time-series changes in plant height, new growth, and mortality over a sixty-three day period. While some growth was evident under all treatment conditions, significant differences in productivity were observed. Visual results showed that plants exposed to high concentrations of oiled sediment (36.5 - 72.9 g/kg) were considerably smaller than those exposed to control and/or lightly-contaminated sediments (<4.56 g/kg). Statistical analyses of weight and stem density data showed that elevated oil concentrations significantly decreased plant biomass. Mortality was significantly correlated to oil concentration and reached 87% in the highest concentration.

Study results indicate that transplants of *Scirpus pungens* were able to survive, grow, and produce new shoots in sediments contaminated with crude oil in a range of concentrations comparable to those associated with oil spill incidents.

HABITRAP: AN IN SITU BIOLOGICAL EFFECTS MONITORING SYSTEM.

***Peter J. Cranford**, Fisheries and Oceans Canada, Bedford Institute of Oceanography*

The HABITRAP is a new biological effects monitoring system that uses bivalve filter feeders as sentinel organisms for environmental impacts and is based on continuous measurement of the feeding and digestion responses of bivalve populations (scallops, mussels, clams, etc.). Commercially and ecologically important bivalve stocks are distributed throughout much of the eastern Canadian continental shelf. Bivalve food acquisition is a sensitive index of organismal and population effects of contaminants as it is closely related to growth, reproductive potential, survival and the ability to contribute to the gene pool. Quantitative feces collections by a sequentially sampling sediment trap (HABITRAP), conducted with simultaneous sequential seston sampling, permits calculation of food ingestion and absorption rates (Cranford and Hargrave, 1994). Laboratory studies have shown that bivalve feeding behaviour is highly sensitive to the presence of a wide variety of contaminants in the marine environment (Donkin et al. 1989 and Cranford et al. 1999). Sea scallop (*Placopecten magellanicus*) clearance rate and absorption efficiency have both been shown to decline when exposed to increasing concentrations of water-, oil-, and synthetic-based drilling muds (Cranford and Gordon, 1992, Cranford *et al.*, 1999 and unpublished data).

The HABITRAP has been extensively tested in coastal and offshore conditions and the measurements obtained have been shown to be both precise and accurate (Cranford and Hargrave, 1994, Cranford *et al.*, 1998, Cranford and Hill, 1999). There are several advantages to using the HABITRAP approach in offshore oil and gas EEM programs.

Continuous monitoring of bivalve feeding processes permits an assessment of the relative biological impact of different drilling operations (e.g. bulk waste dumps or change in drilling fluid). The shellfish are also used to measure the bioavailability and distribution of contaminants. HABITRAP subsamples can be analysed for drilling waste tracers (e.g. barium) to help establish cause-effect relationships. The measurements provide a physiological explanation for any population effects. *In situ* bioassays eliminate problems associated with conducting laboratory toxicity tests under unrealistic environmental conditions.

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NATURAL ATTENUATION REDUCES IMPACT OF THE 1970 ARROW OIL SPILL

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In 1970 the tanker *Arrow* ran aground releasing 2,045 m^3 of Bunker C oil along 300 km of Nova Scotia's coastline. Only 10% of the oil was subjected to cleanup; the rest was left to degrade naturally. Sediment and interstitial water collected in 1993 and 1997 from Black Duck Cove in Chedabucto Bay, a representative untreated site, showed that the remaining residual oil has undergone substantial biodegradation.

The environmental significance of this intrinsic remediation process was assessed with a battery of microscale biotests: CYP1A and mixed function oxygenase induction in winter flounder, Amphipod Survival, Echinoid Fertilization, Grass Shrimp Embryo-Larval Toxicity, Microtox® Solid-Phase and 100% Tests. While much oil remains in the sediment (426-12,744 ppm), results of the biotests show that it is of low toxicity and habitat recovery is evident from the level of benthic diversity.

ENVIRONMENTAL EFFECTS MONITORING

Presentations

ENVIRONMENTAL EFFECTS MONITORING FOR THE COHASSET PROJECT

Mark MacNeill[1] and Stephen Full[2], *[1]Coastal Oceans Associates and [2]PanCanadian Petroleum Limited*

The Cohasset Project, operated by PanCanadian Petroleum Limited since 1996, is the first offshore oil production project in Eastern Canada. The Project is located on the Scotian Shelf approximately 290 km from Halifax. Development for the Project began in 1989, first oil in July 1992 and last oil in December 1999 with a total of 44.4 million barrels of oil produced. Over the years, the field logistics consisted of a Rowan Gorilla jack-up rig, two fixed production jackets, a loading tanker, a shuttle tanker, supply vessels and helicopter operations.

Overall, the project had very favourable aspects for production without any major significant environmental impacts. The project is located in an area that has a very active physical environment (i.e. currents, winds and waves). It is also located in a relatively non-significant fisheries zone, 4Wf, when compared to the rest of the Shelf and the field has a 500-meter vessel exclusion zone surrounding it. The oil produced is a high quality, sweet oil that does not emulsify and evaporates quickly. All of these aspects were taken into consideration when creating the Environmental Effects Monitoring (EEM) programs for the project.

The discharges for an offshore production project are well known and are prescriptively regulated. They include produced water, oil on cuttings, produced sand, deck drains, spills and accommodation wastes.

The Cohasset project implemented four EEM programs to determine potential environmental impacts. These included: 1) benthic grab samples, 2) oiled bird surveys on Sable Island, 3) litter surveys on Sable Island and 4) shellfish tainting studies. The majority of the presentation will concentrate on the fourth program.

The shellfish tainting studies were developed with fisheries, regulator and scientific input to address fishermen concerns with potential taint (atypical odour or flavour). It consisted of mussel buoys deployed at 250m, 500m, 1000m, 1500m and 10km from the field. Each of these buoys measured environmental effects at 10m above seafloor and 10m below sea surface. The buoys were recovered between 2-4 times per year and sent to an independent laboratory for analysis (Canadian Institute of Fisheries Technology) for both qualitative (taste and smell) and quantitative (gas chromotography) effects.

Results of this 7-year study essentially showed that taint and hydrocarbon uptake in the mussels did occur at the Cohasset site. The majority of effects, however, were limited to within 500 meters of the discharges (within the vessel exclusion zone) and hydrocarbon levels quickly returned to background when the discharges ended.

Further information concerning the EEM programs for the Cohasset Project can be obtained by contacting Stephen Full, Environmental Advisor for PanCanadian Petroleum, at (902) 492-5574 or stephen_full@ns.pcp.ca.

HIBERNIA'S PRODUCTION PHASE OFFSHORE ENVIRONMENTAL EFFECTS MONITORING PROGRAM

Dave Taylor, *Hibernia Management and Development Company, D.G. Taylor Inc.*

Introduction

In its Environmental Impact Statement prepared for the Hibernia Project (Mobil 1985) the Hibernia Partners committed to the development and implementation of an environmental effects monitoring program. Subsequently, the C-NOPB in Condition 12 of its project approval decision (Decision 86.01 - C-NOPB, 1986) supported this commitment. Consequently, in April 1996, Hibernia submitted its Production Phase Environmental Effects Monitoring Plan for C-NOPB approval which was granted in May 1997.

The EEM Program

The environmental effects monitoring plan (EEM) was developed through an independent consultant with the involvement of government technical and regulatory agencies and the general public. The plan and hence the program as implemented is founded on an hypothesis testing approach[1] (cf. Thomas (1992)). This approach emphasizes the importance of the hypotheses formulation and testing and of accounting for natural variability in the program design. The hypotheses formulation process demands the

[1] Thomas, D.J. 1992. Considerations in the design of effect monitoring strategies. Beaufort Sea Case Study. Environmental Studies Research Funds Report No. 118. 56pp.

establishment of clearly defined goals and identifies the spatial and temporal scales essential to testing the hypotheses developed.

Hibernia's EEM program established several a priori hypotheses against data would be tested to determine if oil production had induced changes in the adjacent environment. These hypotheses can be summarized as follows:

- Operational discharges to the ocean from Hibernia will not result in major biological impacts beyond a predicted zone of 1000 m from the production platform (yardstick = amphipod toxicity test)
- Operational discharges to the ocean from Hibernia will not result in minor biological impacts beyond a predicted zone of 4000 mfrom the production platform (microtox / juvenile polychete toxicity test)
- Operational discharges to the ocean from Hibernia will not result in taint of fishery resources outside of the fishing exclusion zone which is effectively 500 m from the production platform or subsea loading system (yardstick = controlled taste testing)

To address these hypotheses, Hibernia's Environmental Effects Monitoring (EEM) Program was designed to detect the following, in comparison to baseline data collected in 1994 and for the biological samples in relation to a reference site some 38 km north-west of the production platform:

- toxicity of seabed sediments up to 8 km from its production platform and at control stations at 16 km both north and west of the platform
- contaminants in American Plaice; and,
- hydrocarbon tainting in American Plaice.

Changes in the above-noted variables with distance from the platform and between annual sampling periods are also evaluated.

Seabed sediments and biological samples are tested for a range of chemical contamination including heavy metals and petroleum hydrocarbons (including PAHs). Sediment toxicity is evaluated in the laboratory by first exposing bioluminescent bacteria to sediment collected from some 58 sample points around the production platform. Any samples that elicit a response from the bacteria are subjected to a second round of toxicity tests. These tests employ an amphipod (marine crustacean) and a burrowing marine worm (polychaete). The purpose of the amphipod test is to seek any evidence of acute toxic effects while the polychaete test is to seek any evidence of sub-lethal effects. In addition, sediment samples from the control stations and stations immediately adjacent to the platform (i.e., $\leq$ 500 m) are subjected to amphipod/polychaete tests regardless of their response under the Microtox protocol.

Evidence of hydrocarbon tainting of fish flesh is done with taste testing panels using well-established methods.

Findings and Lessons Learned to 1998

The results of the 1998 field program do not demand that Hibernia reject any of its null hypotheses as stated above. Therefore, it is concluded that Hibernia's operational discharges to date have not resulted in any minor or major effects outside the areas predicted and/or detection of any taint in fisheries resources outside the 500 m exclusion zone.

Only one sample station approximately 250 m from the platform showed a positive Microtox bioassay response and subsequent testing of that sediment revealed no toxic responses from either amhipod or polychaete bioassays. In addition, no evidence of hydrocarbon taint of American Plaice caught within 2500 to 3000 m of the Platform in 1998 could be demonstrated in taste tests.

Analysis of metals and hydrocarbons in the sediments showed that hydrocarbons and metals levels decreased with distance from the platform as anticipated. Hydrocarbons dropped to background in about 1000 m while metals of

interest remained at baseline values or below their limits of quantification with the exception of Barium which dropped to baseline in about 500m. Polyaromatic hydrocarbon levels remained below their limits of quantification notwithstanding the fact that sediment chemistry limits of quantification were reduced significantly in time for the 1998 field season.

To date no differences in hydrocarbon or metal levels between North and South of the platform can be demonstrated indicating either no apparent current effect or that other processes of redistributing these contaminants may be operating. Efforts to date show that the sea bottom habitat in the immediate vicinity of the Hibernia platform does not support significant numbers of scallops to enable them to be used as an indicator organism as originally planned.

Analysis of 1998 sediment chemistry data showed considerable statistical variance among the three cores taken at each station. As a result, during the 1999 field survey additional core samples were taken at randomly selected stations in an attempt to see if this variance would tend to decrease with additional core samples or not. Review of the 1998 sediment chemistry results led to establishment of additional sediment sampling stations around the 500 m sample ring to ensure detection of changes in sediment toxicity or chemistry that might occur between 500 and 750 m from the platform in later years.

NEARSHORE AND OFFSHORE ENVIRONMENTAL EFFECTS MONITORING AT THE SABLE OFFSHORE ENERGY PROJECT

***Geoffrey V. Hurley**, SOE Inc.*

Nearshore EEM Program

The SOE Inc. gas pipeline approaches the Nova Scotia landfall site at Goldboro through an outer bay (sometimes called Stormont Bay) common to Country and Isaacs Harbour. This nearshore region is an active fishing region particularly for the residents of Goldboro, Drumhead, Bickerton and adjacent communities. As the pipeline passes through the outer Bay, the water depth increases to 20 m at a distance of approximately 1200 m from shore. To protect the pipe over this 1200 m to the landfall, the pipe is buried in a trench throughout this region.

In order to determine whether any observed temporary or permanent environmental perturbations may be attributable to the project, the monitoring program was planned in three parts[2]

- a baseline study to describe normal conditions and seasonal variations.
- a construction monitoring program to assess conditions during execution of the project
- a recovery monitoring program to ensure that any persistent changes are documented.

Construction of the trench, pipeline installation and subsequent backfilling of the trench were considered. Valued Ecosystem Components (VECs) were identified, together with their sensitivities and critical periods. Potential pathways from the project construction activities to the VECs established the primary components of the baseline study.

A community based Inshore Fisheries and Aquaculture Liaison Committee was established as a direct link to the users (fishermen) in the region. The committee met monthly during the baseline and construction monitoring phases and community concerns were reflected in the program's initial focus and subsequent

[2] SOE Inc.'s nearshore EEM Program was designed and implemented by Martec Limited

modifications. The Sable Offshore Energy Environmental Effects Monitoring Advisory Group (SEEMAG) provided advice and feedback on the monitoring program.

Among the study components included for the baseline, construction and recovery programs were: hydrodynamics and sediment modelling and monitoring, sea bottom conditions, benthic biota and cultivated mussels, water quality, phytoplankton and resuspension of toxic cysts, terns and other seabirds, and historical site surveys.

A comprehensive baseline and construction program was designed and implemented to address each of these issues and evolved into a focus on specific indicator species, modelling and measurement of sediment behaviour, monitoring changes in bottom conditions.

Suspended sediment and sediment deposition levels were established during all phases of construction (trenching, pipelay, subsea trenching and trench fill-in) using numerical hydrodynamic and sediment dispersion models. Monitoring of suspended sediment during construction confirmed levels were low (generally <60 mg/l at a distance of 1200 m from the trenching vessel), as predicted from numerical modelling and well within compliance levels (200 mg/l at 250 m, 50 mg/l at 400 m) established for the operation. Storm conditions produced high concentrations of suspended sediment throughout the Bay and their overall effect in each large storm is much larger than the measured effects of pipeline trenching.

The effect of construction on sea bottom conditions was measured by diver bottom sampling of diversity and abundance of marine organisms. Permanent benchmark sites established at 9 locations throughout the Bay have been revisited four times during the monitoring program, and no significant bottom changes have been observed at these sites.

Monitoring programs were established for sea urchins and mussels, two important commercial species. The sea urchin program involved intensive sampling along the pipeline trench region, as well as regions throughout the Bay, more removed from direct construction activities. Abundance of sea urchins was monitored within 250 m of the pipeline construction and at two control locations either side of the pipeline approximately 2 km away from trenching activities. The abundance of commercial-sized sea urchins within the pipeline corridor and at the inside control station showed a decrease of approximately 60% between 1998 and 1999. The control station in the outer harbour had a slight increase between years, but overall densities of commercial sized urchin remained considerably lower than at the other two sites. It is important to note that, within each area surveyed, there is considerable variability between transect lines short distances apart. Post-construction monitoring will focus on recovery of urchins in the immediate trench region. Monitoring of mussel spat settlement and mussel tissue condition at an aquaculture site has shown that there has been no measurable effect on this species. Similarly, lobster trapping near the pipeline trench region yielded similar catches before and after construction.

Water properties (temperature, salinity, oxygen levels) were monitored throughout the Bay and samples were taken for potential blooms of toxic cysts due to construction disturbances of the bottom. No indication of change due to construction was measured.

No measurable changes in bird behaviour or foraging patterns that could be attributed to construction activities were detected during construction monitoring of terns and other seabirds. Nesting and fledgling of all terns, including Roseates on Country Island, was highly successful in 1999 compared to recent years.

Visual reconnaissance and documentation of two shipwrecks in the Bay (classed as offshore heritage resources) was carried out prior to

construction and a video in August 1999 showed no construction effects.

Given the appropriate lead time required for a thorough baseline study, and with up-to-date numerical modelling tools, monitoring programs can be set up to measure environmental effects accurately. Community participation in the monitoring program ensures that concerns be addressed early and on an ongoing basis. Flexibility in program scheduling and selection or reduction of program components throughout all three phases of the monitoring can improve the program output.

Offshore Monitoring Program

SOE Inc. is required to develop and conduct an Offshore EEM Program as a condition of the Development Plan approval granted by CNSOPB. According to SOE Inc.'s Development Plan, the EEM Program was designed to test impact predictions made in the EIS and collect data for environmental management decisions. The Tier 1 EEM Program focuses mainly on the activities at Venture, Thebaud and North Triumph. Drilling was conducted at all three locations by December 31, 1999. Baseline information was collected in 1998 and 1999[3]

The environmental attributes chosen for the Offshore EEM Program were based on VECs identified during the EIS process and attributes identified by SEEMAG and the EEM study team. The selected attributes include: water quality, suspended particulate matter (SPM) in the benthic boundary layer (BBL), sediment quality (chemistry and toxicity), benthic habitat and megafaunal community, shellfish body burden and taint, marine mammals and seabirds. The sampling design consists of a radial grid with eight axes. Sampling is conducted along transects at increasing distances from each platform (250 m to 20 km).

Water samples collected on a transect (250 m to 2 km from the drilling platform) and in profile along the axis of the prevailing current did not contain detectable levels of hydrocarbons during the drilling phase surveys. An apparent plume was detected only once out to 500 m from Venture during the Fall, 1998, survey.

There were no significant differences in either SPM or barium concentrations in the BBL around the three drilling platforms that can be attributed to drilling activities. Bentonite was not present as a component of the SPM.

Drill cuttings piles were visible within 70 m of the discharge pipe. Elevated levels of total petroleum hydrocarbons (TPH) and barium were generally found at 250 and 500 m from the drilling platforms and were short-lived. Dispersion or burial appeared to occur within a six-month period and is likely attributable to sediment transport.

Sediment toxicity was observed in amphipod mortality testing and in echinoid fertilization testing at stations throughout Venture, Thebaud and North Triumph fields for the baseline surveys. Microtox testing on sediment samples from all fields during baseline and drilling phase surveys showed no toxicity. Amphipod toxicity at 250 m at Thebaud and North Triumph correspond with elevated TPH levels.

The dominant epifauna in the Venture and Thebaud fields are sand dollars, and the dominant epifauna at North Triumph are brittle stars with sand dollars. No obvious effects on benthic fauna or habitat are evident.

Scallops collected from natural beds in the project area showed low levels of aliphatic hydrocarbons in baseline and drilling phase surveys. No taint was detected in sensory evaluations. In mussels moored at Venture, small amounts of hydrocarbons were detected from 500 m to 13 km and in the control sites. The concentration of hydrocarbons detected in mussel

[3] SOE Inc.'s offshore EEM program was designed and implemented by Jacques Whitford Environment Limited

tissues was not solely attributed to hydrocarbon releases from discharged drilling muds. High peaks of pristane are evidence of healthy feeding mussels.

The data generated from observations of marine mammals and seabirds made by trained observers provided no evidence of avoidance or attraction to the project area by these animals.

For the ongoing offshore EEM, the practicality, logistics and analytical limitations of some parameters should be reviewed, as well as modifications of sampling locations and effort.

TERRA NOVA ENVIRONMENTAL EFFECTS MONITORING PROGRAM

Urban Williams[1] and Mary Murdoch[2], *[1]Petro Canada and [2]Jacques Whitford Environment Limited*

The Terra Nova oil field is situated on the Grand Banks, about 35 km southeast of the Hibernia oil field and about 350 km east-southeast of St. John's. Petro-Canada is the operator of the field on behalf of the owners. The oil field is being developed using an FPSO (Floating Production Storage and Offloading) facility with a drill rig (*Henry Goodrich*) being used to drill the wells. Approximately 24 wells will be drilled through seven subsea templates located in four glory holes to protect them from icebergs. Trenched flowlines connected to flexible risers will link the subsea installations to the FPSO. The FPSO will offload to shuttle tankers. The FPSO is expected to be at the site in late 2000 with First Oil anticipated in the first quarter of 2001.

One of the first steps in developing an EEM program is to describe the existing environment. To this end, baseline data were collected in 1997 from the Terra Nova site and form the foundation upon which the EEM program is structured. Design of the EEM program was submitted to the Canada-Newfoundland Offshore Petroleum Board in November 1998. The Terra Nova EEM Program will be implemented during the summer of 2000. The EEM program will be conducted yearly for the first three years beginning in 2000. Subsequent scheduling will be determined after a thorough review of the EEM data.

The purpose of EEM is to determine and quantify change in the surrounding environment related to routine project operations. Several steps were taken in designing an EEM program to meet this purpose. The first step was to develop a strategy for EEM. The EEM design team reviewed existing information about the Terra Nova site, the region and offshore oil EEM programs in the North Sea and the Gulf of Mexico. Stakeholders were consulted for their input including the local public, government agencies, and regional/international experts. Next, the liquid and solid discharges from the project were identified and described. A conceptual model was then developed linking project discharges and possible effects to the environment, including marine resources in the area. Information derived from these activities was used to generate a set of predictions and hypotheses to be tested in the EEM program.

The next phase in the process was (i) to examine possible variables for monitoring, (ii) develop an appropriate statistical design to address the hypotheses, and (iii) formulate an appropriate sampling program. Following careful consideration, the Terra Nova EEM design team chose to include in the monitoring program commercial fish species, water quality and sediment quality. Seabird and marine mammal monitoring will be conducted under separate programs from the EEM, including observer programs and the contingency plan in the event of an accident. Two spatial models will be used to the EEM program: (i) a regression or gradient design and (ii) an ANOVA or Control-Impact

design. The gradient design will be used to monitor water column and sediment chemistry, sediment toxicity, and benthic invertebrate communities. The Control-Impact design will be used to monitor larger and more mobile fish or shellfish.

Year 1 of the Terra Nova EEM program will be conducted during mid-2000, with results being available during the first quarter of 2001. Results will be evaluated to determine impact predictions, provide early warning of potential future challenges, provide information to managers to allow for decisions pertaining to the marine environment, and provide the basis for technological improvements.

Posters

OFFSHORE HYDROCARBON DEVELOPMENT—ENVIRONMENTAL MANAGEMENT AND ENVIRONMENTAL EFFECTS MONITORING

Kay Kim, Debbie Wallace, Lucia Fanning and Andre Gauthier, *Environmental Protection, Environment Canada*

An overview is given of the role of Pollution Prevention (P2), environmental management systems (EMS) and EEM in enhancing environmental management in the offshore oil and gas sector. Good environmental management can minimize impacts to the environment as well as reduce operating costs, financial risks and liabilities, improve productivity, increase profits and enhance corporate image. Good environmental management is facilitated by the establishment of an EMS and the adoption of a P2 approach.

OFFSHORE HYDROCARBON DEVELOPMENT—AQUATIC ENVIRONMENTAL EFFECTS MONITORING

Kay Kim, Kim Coady and Roy Parker, *Environmental Protection, Environment Canada*

Offshore oil and gas activities in Atlantic Canada have increased substantially over the last number of years. Operational discharges, including drilling muds, drill cuttings and produced water, have caused environmental impacts in the marine environment. One of the most noticeable aquatic environmental effects associated with operational discharges is the impact on the benthic community. Smothering of the ocean floor by drill cuttings, changes in sediment grain size and composition, and anoxia due to the decomposition of organic base fluids have impacted the marine benthic community (Daly, 1999). While these impacts may be of limited duration, any environmental damage arising from offshore oil/gas activities, although localized, should be minimized. This poster will focus on the adequacies of the existing EEM programs, the use of EEM data, and research needs as seen by Environment Canada.

ENVIRONMENTAL RISK ASSESSMENT OF WASTES FROM OFFSHORE OIL OPERATIONS

Rehan Sadiq, Mukhtasor, Brian Veitch, Tahir Husain, Neil Bose, *Memorial University of Newfoundland*

Offshore oil operations generate wastes during different phases of drilling and production, which pose threats to the ecological community and human beings. Exploration and development drilling operations generate rock cuttings to which drilling fluids and formation oil can adhere. The contaminants present in this waste stream partition in the water column, sediments, and biota. A probabilistic model is proposed for evaluating the concentration of organic priority pollutants and heavy metals using the fugacity/equivalence approach. This model helps in predicting the distribution of pollutants in a multimedia environment. Probabilistic evaluation of concentrations in the water column and pore water determines uncertainty in ecological and associated human health risk. A tradeoff analysis employing fuzzy composite programming (CP) is used to evaluate various discharge scenarios.

In the production phase, produced water discharges dominate drilling wastes. Our research investigates hydrodynamic mixing and ecological risk assessment associated with produced water discharges. The hydrodynamic modeling is carried out to develop a probabilistic initial dilution model, which is subsequently integrated with far field dispersion models. The integrated model is then used in ecological risk assessment of produced water. Ecological risks are simulated for different scenarios of produced water discharge, the results of which can be used to identify the best discharge scenario.

PART B. PERSPECTIVES AND DISCUSSION

KEYNOTE ADDRESS

The ecological framework for environmental effects monitoring: A perspective from outside the region

Dr. J.P. Ray, *Equilon Enterprises, LLC / Shell Global Solutions, Westhollow Technology Center, Houston, TX*

Introduction

The study of the effects of offshore oil and gas activities, whether due to physical perturbations, or to the fate and effects of various discharge streams or accidental spills, is not a new realm of endeavour. In fact, intensive investigations have been ongoing on a global basis for over two decades which have chronicled offshore activities which go back to the early 20th century. These broad ranging environmental assessments have occurred in a wide diversity of habitats, ranging from coral reef, seagrass, and mangrove areas, to the arctic regions of the Beaufort Sea (in both the Alaska and Canadian waters). Studies have included assessments on the fate of discharges such as drilling fluids, and produced water. They have also addressed acoustic issues on the behavior and migration of marine mammals.

An important realization is that there is already a considerable database of scientific knowledge on the characterization of the wastes, their fates in the marine environment, and their zones of biological influence. In the water based drilling fluids arena alone, a rough estimate over a two decade period places the level of monitoring and scientific investigation at around $200 million (US). Overall, the U.S. regulatory agency responsible for leasing and monitoring of offshore lands in the U.S. for oil and gas, has spent in the neighborhood of $750 million on their Environmental Studies Program (some of these studies were onshore and related to socio-economic issues).

These many studies have been partially summarized in the books that have been published from many symposia (see attached bibliography). The important point to be made from all of this research is that we need not reinvent the wheel every time we move into new exploration areas. The basic principles of science prevail, no matter where you are. Every geographic region has its own uniqueness; the species will differ, as will their life cycles. But, the range of responses noted will not usually vary tremendously, e.g., by orders of magnitude. What this really suggests is that instead of doing all studies from scratch in a new area, and requiring costly, long term monitoring at every single location, a more prudent strategy would be to first identify what is really unique and different about the particular area of interest. Then, a selective monitoring and assessment program should be designed to validate the data and conclusions drawn from studies in other areas of the world. A selective, focused program of this type can greatly reduce the long term environmental monitoring costs, yet still provide a scientifically sound basis upon which regulations can be based.

Key Issues

What is being discharged or spilled? It may sound like a simplistic question, but it isn't. Try to figure out from an operator exactly what the composition of a mud or produced water is. It's not a trivial question and you need to understand that in order to design environmental monitoring and to analyse the results. How much is being discharged? Many people don't have a really good quantitative idea. How often is a discharge occurring? When you look at a drilling program, you may find you only have discharges going out 50 percent of the time, but people think it is a continual exposure. Where are things going in the environment, and how long are they going to be there? What are the short and long term effects? Both are very important.

Early Problems

In the US we encountered a number of problems early on.

- Trust. Nobody trusts big oil—neither the public nor the regulators. This is something we have been working on for a long time.
- Proprietary information. You won't necessarily be able to get information about the exact constituents of drilling fluids or the treatment chemicals in produced water, which makes environmental assessment more difficult.
- Quality of the research. The qualifications of the organization or people doing the research were not always adequate.
- Funding. Who is going to fund the research or monitoring?
- Permits. Quite often there was difficulty getting permits to carry out the studies. Canada is forward enough to actually do field trials with oil. US companies have had to go to other countries such as Norway and Panama. For one study on dispersants, many years ago, it cost $250,000 simply to get the permit.
- Peer review and publication. Often the studies do not produce the kinds of reports a refereed, peer review journal wants. But that doesn't mean that you shouldn't publish the information and get it out through a peer review process to ensure the quality of the research. One of the problems in the North Sea is that, for half the studies carried out in the past, the reports are unavailable. This is a problem for process. *"If you don't let me see the data, I don't trust you"*. It's very important to have an open process for sharing the data you produce.

Experience in the 1970s and 80s

In the 1970s and 80s there was a lot of work done on the fate and effects of oil, including laboratory and field studies, and work on dispersants. This involved considerable collaboration between the US and Canada. Canada was a leader particularly on the freshwater side. In the US we were able to do studies in the field on small scale oil spills and the use of dispersants. Those kind of trials are no longer allowed. For water based muds I estimate that over $200 million have been spent in the US doing research on their fate and toxicity. And yet, in many places in the world, people are reinventing the wheel and repeating these studies.

Much effort has been put into studying the physical, chemical and biological fate of oil in the sea, toxicity, dispersants and remediation (both bioremediation and physical remediation). Dispersants were thought to be really bad stuff, but eventually it was realized that they can, in certain circumstances, be the best early response and a valid way to avoid major impacts.

Work on water based muds included studies on:

- Tanner Bank (100 miles off the coast of California), considerable work on sediment traps
- Cook Inlet (Alaska) with a 20 ft tidal range

and 6-8 knot currents, studies around the Ocean Ranger

- Mid-Atlantic, including some sediment tray work in about 5-6,000 ft of water
- Georges Bank, a good fate study was done on an exploratory well there some time ago
- Gulf of Mexico, majority of the offshore oil and gas industry is in this area and hence most of the studies
- Beaufort Sea, some interesting work on ice and gravel islands in 5-10 ft of water.

These represent a broad variety of environments and every one of them poses different problems for environmental monitoring design. The topics addressed included water column fate, sedimentation, benthic effects, long term fate, and toxicity testing for metals and bioaccumulation.

1980s and 90s

In the 1980s and 90s, most of the big issues around water based muds were resolved, when produced water reared its head. The composition of produced water is a can of worms. Different produced waters from different areas or even from the same formation can vary a great deal. One of the issues in the Gulf of Mexico, because we have such large volumes of produced water, is human health effects, ranging from effects on the local sport fisherman who catches snapper and grouper round the platform to people who eat the shrimp caught commercially. How the water is discharged, whether above, at or below the water surface, makes a difference to its fate.

Naturally occurring radioactive materials (NORM) have been studied. We were interested in the soluble and colloidal size particles that come out of the pipe. We've done a lot of work with plants and animals and collaborated with national labs to carry out human health risk assessments

Three of the key produced water studies include:

- American Petroleum Institute coastal study in 30 feet of water and also just inside the mouth of an embayment in Louisiana, getting into some worst case shallow water scenarios
- Department of Environment study of a discharge in a shallow bay that was shut off, following up on how fast recovery occurred. This included an offshore component and cost approximately $5 million.
- Gulf of Mexico Offshore Operators Committee (OOC) bioaccumulation study, looking at uptake of produced water analytes at a range of production platforms in the Gulf. Three summaries drawn from this study are included in the appendix to these proceedings.
- Gulf of Mexico Offshore Operators Committee Bioaccumulation Study

The OOC study[4] consists of about 120 offshore operators in the Gulf. USEPA wanted to determine whether there was a human health risk from produced water discharges. They decided that any platform discharging over 4,600 barrels a day (bbl/day) would have to do a study. This would have meant over a hundred individual studies costing about $300,000 each. Instead OCC and EPA agreed that a joint industry program, getting good quality data from a smaller number of platforms, would be preferable from both a cost and scientific perspective.

The study looked at target chemicals in the tissues of both fish and invertebrates. This was an EPA mandated requirement, which is why we didn't look at some of the other things like selected organs. We worked with a couple of different species of mollusk and numerous species of fish, choosing those that would tend to be more platform resident rather than migratory.

[4] Summaries of three components of the OCC study are included in the Appendices

We took that data, in conjunction with world literature, and did both an ecological and human health risk assessment (the definitive component). EPA also wanted a broader survey across the Gulf. This survey component was not as intense, but covered areas near the Mississippi River, shallow waters in less that 10m, and the centre of the oil patch where there was a high density of platforms, to see if there were elevated levels of target chemicals.

While there are some platforms in the Gulf discharging around 100,000 bbl/d, about 91 percent of the platforms fall below the 4,600 bbl/d threshold. Selection criteria also took into consideration the distance between the platform and both other discharging platforms and other potential sources of contamination. We are dealing with very low levels of metals and organics and when you have the Mississippi River, the oil patch and marine transportation all contributing, it doesn't take much to get conflicting signals. We were trying to tease apart signals so we could see if produced water was really having an effect.

We did a preliminary screening survey of the candidate sites. It might look good on paper, but it might not be what you think it is when you get there. For example, the first platform we visited didn't have enough of a biological community to support our sampling pressure for a couple of cruises.

The discharge rates at the selected platforms ranged from 11,000 bbl/d (~ 1,848,000 litres/day) to 5,200 bbl/d. It was particularly important to compare the same species in approximately the same age class between locations. That makes it more difficult when you are trying catch fish. We also needed to collect enough data so we could determine from a statistical perspective what kind of sample size we needed to be able to detect change. It is important to know you have sufficient numbers of animals to do the study. This can be a big problem with harvesting mollusks off the platform. When you have to come back and do it again a year later, you need to be sure you have enough.

You also want to pick species that are going to be exposed directly to the plume or eat other organisms that are exposed. We had to use spear fishing and trapping as well as hook and line, so we could selectively get the species we wanted. If we went out there with hook and line to get whatever we could catch, it would have been a great fishing trip, but a costly research program.

The bottom line was that there was no significant bioaccumulation that posed a threat to either human consumers or marine biota. There were small elevations of target chemicals in some locations and not in others. In some reference sites there were also small elevations compared to comparison sites.

Synthetic Muds

We have been working closely with the EPA on regulations for synthetic muds in the last few years. We have a stakeholders group consisting of

- EPA Office of Research and Development
- Four EPA Regions
- Department of Energy (two national laboratories)
- Department of Interior Minerals Management Service
- American Petroleum Institute
- National Oceans Industries Association
- Individual stakeholder companies
- NGOs.

EPA has reasons why they wish to pursue the regulation of synthetic muds. We have looked at North Sea data over the last few years, and the decisions they have made, and have decided to verify the findings ourselves because our environment may be a bit different. If the results are similar to those in the North Sea, we may end up not discharging synthetics. If it is different, and EPA thinks our regulations are adequate, we are going to control and discharge muds associated

with our cuttings. In shallow water in the Gulf in 1997, we have about 1100 wells drilled, with another 170 or so in deep water. The deep water sector is increasing quite rapidly. There are actually six different groups set up to do the research needed to get the synthetic mud information EPA needs to make decisions.

We are developing a new standardized solid phase bioassay, both as a qualifying tool and as a compliance monitoring tool. We are not only looking at the solid phase biodegradation test that's used in Europe but we are also developing a couple of approaches to doing biodegradation determinations. For environmental effects, we have a two and a half year program looking at 5 platforms on the Shelf and 3 in deep waters out to about 1200 m. The first cruise will occur in April.

Lessons from the Past

I have encapsulated what I feel to be many of the mistakes made in past studies, and what I consider to be the "learning's." These are universal, and not specific to the Gulf of Mexico or the U.S. These very same shortcomings, problems, and learning's have occurred world wide in study after study. I'm sure that many of these same observations have been made from past Canadian environmental studies. To complete my review, I have also tried to identify some facets of the recent past Canadian studies conducted relative to the development of Atlantic Canada. These observations were not intended as criticisms, that is why in the presentation, they were entitled "Points to Ponder." Hopefully, they will be cause for reflection as to the appropriateness or relevance of some of the approaches and findings.

Usually, environmental studies conducted relative to offshore oil and gas are the result of regulatory requirements. They are often driven by an inadequate information base, and sometimes driven by political forces. Regardless of the cause or source, they are related to regulatory needs. The fact is, most petroleum producers have limited environmental expertise on their in-house staffs. Therefore, it is incumbent on the companies, sometimes with the help of the regulatory agencies, to identify those outside consultants, academics, and sometimes government researchers, to conduct the programs. The fatal flaw quite often occurs at the design stage of the program. If those responsible for designing the program do not understand the operations, the receiving environment, the activity or pollutant, the fate and effects, and the ecosystem they are dealing with, then they may not design a scientifically sound program. Unfortunately, over many years, we have seen many a program that was designed or dictated by individuals who are not qualified. This results in studies that are non-conclusive, and whose data cannot support the conclusions.

At the risk of my logic train jumping around, I will briefly mention and highlight some of these past weaknesses. It begins with a lack of trust between the involved parties: regulators, operators, and the public. This can cause problems throughout a project. Sometimes the projects are their own worst enemy because of poor data quality, lack of peer review, and limited distribution of the results. The standard reaction to not being allowed to see the data is that there must be something to hide!! Often, the data comes out years later and is of limited use.

Laboratory vs. field: all too often, we choose surrogate species, and test them under lab conditions that have no relevance to field conditions or exposure regimes. This leads to false assumptions about what really may be occurring in nature. Another facet that relates to both laboratory and field studies is the lack of good statistical design. The classical mistake is to design a sampling program, collect and analyze the data, and then sit down with it and try to figure out which statistical approach to use.

There are also ongoing problems associated

with sample sizes, contamination from other non-related sources (e.g., river inputs), analytical methods, and detection limits. Another analytically related issue is the lack of consideration for chemical speciation (e.g., total chrome versus Cr^{+3} or Cr^{+6}). In many studies, we either select the wrong biological species from the field to study or analyze, and sometimes we put surrogate species into the field for *in situ* testing. The mistake is in putting an animal into an environment where it doesn't normally live, or exposing an organism in an environmental niche where it doesn't occur. A good example was a study done many years ago where coastal, brackish water oysters were put in cages and placed near an offshore platform almost 100 miles offshore. There is a common expression which bears a lot of wisdom, "If an animal doesn't live in a particular location or niche, there is probably a good reason why!" In this particular example, the oysters were subjected to marine predators that don't occur in brackish water, and they also starved to death because an inadequate food was available in the clear blue oceanic waters. The exposure issue is also important, and often ignored. For example, why would you expose a demersal fish that usually lives at depths of 100 m to a produced water plume that doesn't penetrate to a depth of more than 30 m after discharge?

Quite often in the past, studies have missed the mark because the design has focused on minute details, and not first considered the Big Picture. We need to be sure that the context of what we are studying helps us understand the Big Picture. Although often considered slightly sacrilegious by some scientists, the "So what?" question is still relevant. Is the question being asked really relevant and does it make any difference in the context of what you are trying to understand or regulate? When budgets are always a problem, this is an important question to ask. Similarly, we have wasted millions of dollars in the past because we continue to reinvent the wheel. Instead of making use of pre-existing information from other parts of the world, everyone feels that their area is unique, and that everything has to be redone there. There are certain unique characteristics, but a large percentage of the pre-existing data is relevant. The prudent approach to managing limited research budgets is to identify those variables that are truly different for a region, and then design validation programs to verify the differences, and to assess whether or not the fate or effects are significantly different from what is already known.

You can conduct the best monitoring programs, but unless they are conducted in an open manner, and bought into by all interested parties, the results will not be accepted and used. It is imperative to establish a feeling of trust between the key participants. A completely adversarial relationship between the regulatory agencies and the industry is counter-productive, and can lead to unnecessary and costly studies, not to mention time delays and costly court challenges.

Again, reflecting on past studies, some very basic principles quite often seem to be forgotten. It is imperative to have a good QA/QC program that is defined in a written document, and adhered to. We have found that having a single, dedicated QA/QC officer responsible for the entire program, even when multiple contractors are used, is the best way to ensure compliance. In conjunction with the QA/QC program, all essential tasks should have a written Standard Operating Procedure (SOP) document. Programs should have well defined data quality objectives that are in alignment with the project objectives (e.g., are the detection limits low enough?). The statistical design of the program should be determined in advance, not after the data is collected. Budgets will always constrain the number of samples allowed, but caution should be taken when the sample size becomes so small that adequate statistics cannot be used.

Reference stations are critical to any study.

One of the most difficult aspects of offshore studies is to account for natural variability. The distribution of sediment types and their composition, and biological communities and their diversity and abundance of species, can sometimes vary considerably over small spatial scales. If this variability cannot be determined, then it becomes extremely difficult to determine what was related to the oil and gas activity or discharge. The conduct of screening cruise(s) can allow adequate information to be collected to make these determinations which are critical in finalizing the sampling and analysis plan.

Many projects now include an external review board to oversee the project. These Quality Review Boards (QRB) provide an ongoing peer review of the projects progress and alignment with the technical objectives. For field studies, it is always of value to invite the regulatory authorities associated with the project to join in the cruises.

Quite often projects pursue objectives that aren't scientifically valid, or that cannot provide the desired data and results. One way to ensure that the programs stay focused and realistic is to have the regulatory bodies requiring the studies participate in the cost sharing. I am sure that this recommendation will not be looked on favorably by the regulatory agencies, but believe me, it can make a big difference in the reasonableness, relevance, and cost of future programs. Past history has shown that requirements become a lot more realistic when everyone has money on the table, and its expenditure has to be justified from available budgets.

And finally, for general learning's, it is prudent to make your own, regional regulations, and to not *de facto* accept rules and regulations from other parts of the world. After a review of the specifics of the regional environment and industry operating practices, and in light of the existing literature and any site specific data from your region, tailor make the regulations to fit the local needs. This is exactly why the U.S. industry and the Environmental Protection Agency are spending several million dollars and a couple of years to determine what kind of regulation is required for the use of synthetic based muds in U.S. waters.

Observations on the Canadian Program

Based on some preliminary review, and listening to the many interesting presentations at the conference, I was asked by the organizers to offer some observations on the Canadian offshore monitoring programs. The first point that was very obvious was that many of the "learning's" discussed above have already been taken into consideration in the design of the recent Canadian offshore programs. Environmental research and monitoring programs are not new to Canadian scientists, who as a matter of fact have helped contribute to many of the learning's discussed above. The only really new wrinkle is that the current programs are focused on Canadian offshore environments relative to oil and gas activities.

Most impressive was the use of new methods and instrumentation for the measurement and collection of data offshore. Some of the approaches are state of the art, and are addressing some of the more pertinent information needs, such as bottom boundary layer effects, and the resuspension and transport of settled materials. Also impressive was the considerable incorporation of models into predicting and trying to understand the fate of both natural and anthropogenic materials offshore. One of the important approaches observed was the open, and cooperative working relationship that has been organized under SEEMAG for designing and managing programs in the Sable Island area. In order to keep the studies properly focused and address the key issues that are of major importance to those with regulatory responsibility and to the public, the open process is very important. It also creates trust and buy-in to the

final results.

In the preparation of my comments for the presentation at the conference, I felt it inappropriate to really consider any of my comments to be "criticisms." I felt a better approach was to address my comments as "Points to Ponder", which is how my presentation slides were titled.

The use of models are important, and can be an important tools in understanding processes, and quite often in developing field sampling approaches. One important caveat to consider is the importance of field verification of the models to confirm whether or not the model is adequately predicting what is actually happening in the real environment.

One of the approaches being used in the Canadian studies is to use caged animals to monitor a range of responses, from growth, toxicity, and behavior, to bioaccumulation. We must ask ourselves the question, if an animal doesn't exist in a specific habitat, nor do any similar species, or if that organism would not normally be exposed in a normal operating condition, can atypical exposures really predict impacts? Where else, at 100 km offshore, would you find mussels permanently located in the water column, unless they were attached to an offshore platform?

In many of the studies, we often get wrapped up in our ability to measure and detect analytes at lower and lower levels. A general statement that should be considered is, "Just because we can measure it doesn't mean that it is bad!" We need to be sure we keep the chemistry in balance with our ability to interpret what it means. It is also important to remember that analyte speciation is important. So often, we see measurements that are just total amounts detected. This can be very misleading. For example, Cr^{+6} is much more of a toxic biological concern than Cr^{+3}. Similar comparisons can be made for BaCl versus $BaSO_4$, or the various forms of arsenic.

Is the bullet pattern for sampling design around a point source the best approach? Can statistically designed zone sampling strategies be more appropriate under certain conditions? In contrast, do you really know enough about the water mass movements that you can focus sampling station and monitoring arrays along a single "downstream" transect? Different locations and different hydrodynamic regimes might suggest alternate approaches. Very seldom do we find locations where currents are unidirectional all of the time. Quite often, this is overlooked, and sampling is focused and biased in one direction. Without detailed monitoring, the investigator cannot say with certainty what the deposition exposure was over a selected set of stations.

Are laboratory exposures really realistic when compared to what happens in nature? Quite often the answer is no. Are some of the approaches taken in the Canadian lab testing realistic? Maybe not. Consider the chronic lab exposures to planktonic species for produced water effects. In the laboratory, we create an artificial condition where we expose the animals (and sometimes plants) to constant concentrations (sometimes declining concentrations) of the pollutant of concern. Some of the data in the recent studies were based on exposures of a week or more. Do these planktonic species see chronic exposure when drifting past a platform's produced water outfall? The answer is no. Based on numerous field studies of produced water dispersion, we know that the initial dilution of the produced water is in the range of 100:1 within the first 30 seconds. With 1-2 hours, the dilution is excess of 1000:1, and the actual concentration of the produced water is reaching ambient levels and is no longer detectable. For the small percentage of plankters that would have been entrained in this plume, they have gone from full exposure to almost no exposure in a time span of 1-2 hours in most cases. Is this a chronic exposure compared to the week or longer lab tests?

Are Microtox responses bad? It depends on how the threshold response is defined, and to what species it is calibrated. In some of the presentations, the Microtox response to some of the sediments were considered "hits." In fact, based on the soils criteria, a response was noted in the Microtox test. Without knowledge of what the actual causative analyte was, and without cross calibration to marine species of interest, it cannot be assumed that the Microtox response is a "toxic hit."

The conduct of produced water toxicity identification evaluations (TIE's) will be difficult and expensive. After several years of research in the U.S., efforts were terminated. Because of the relative low level of toxicity, the high dispersion rates, and the physical lack of treatability methods that would effect low concentration components in solution in the produced water, the issue became a So What? item. As long as the produced waters permitted for discharge meet the regulatory agencies toxicity limitations, discharge is allowed.

The Canadian offshore industry is in its infancy. A range of research and monitoring programs will be required so that Canadian regulatory authorities can confirm that the fate and effects of relevant substances seen in their waters are comparable (or different) from what the world's literature shows from other areas. But this verification stage should happen fairly quickly, and hopefully, the offshore program will shift into a long term monitoring mode (if deemed necessary). In the U.S., after a couple of decades of study, standardized monitoring programs are not required.

It should be apparent that site specific monitoring is not feasible, nor necessary at every single well site and platform to be drilled or put in place in the future. The cost effective and prudent course would be for the government and industry to start planning a path forward that would allow cooperatively planned and managed programs that would provide periodic monitoring at selected locations. Once the zones and levels of impacts have been delineated for Atlantic Canada, the only ongoing monitoring will be that required to ensure that compliance is occurring and that regulatory requirements are adequate to protect the valuable marine living resources.

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PANEL DISCUSSION

The role of environmental effects monitoring

***Cal Ross**, SOE Inc., Moderator*

Panel Members

Mark Butler, Ecology Action Centre
Brian Giroux, Scotia-Fundy Mobile Gear Fishermen's Association
Inka Milewski, World Wildlife Fund
Chris Milley, Mi'kmaq Fish and Wildlife Commission
Charlie Warner, Strait of Canso Fisheries Liaison Committee

Mark Butler, Ecology Action Centre

I would like to make the following comments on the presentations and discussions on the first day of the workshop:.

There is a problem when biota move through the impact area and out beyond it to where there is no monitoring. Animals may be affected but the impact is not identified.

Monitoring should be adjusted as project(s) proceed to study cumulative impacts particularly when other industries (shipping and fishing) are contributing to pollution.

There needs to be clearer identification of chronic versus acute lethal impacts.

The significance of impacts varies according to the receiving environment—the nearshore environment, Georges Bank, shelf slope etc. will respond differently.

Sensitive areas and sensitive species should be avoided for oil and gas development.

The oil and gas industry needs to be sensitive to its impact on species that other industries are dependent on—whale watching as part of ecotourism, for instance.

Dilution is so great on the shelf that drill cuttings appear to disappear. This suggests that a problem has gone away when it may not have.

Properties are being licensed onshore and offshore with no environmental screening required before the license is issued. Also, interested parties are given no opportunity to comment or be part of the process. For these reasons, the bidding process should be changed. There should be screening by Environment Canada and DFO before an area is nominated, and the public should be involved—particularly in sensitive areas. In the UK the issuance of new licenses has been halted until new areas have been assessed. In the US many areas are closed to oil and gas development, and in Norway an area is considered closed until a decision is made to open it.

Nova Scotia has no effective energy policy. The approach of the government seems to be to open up areas to development as quickly as possible. This has implications for energy efficiency and conservation. At this time, the government is making commitments with respect to climate change and I would like to see how this expanded development intersects with those commitments.

Chris Milley, Mi'kmaq Fish and Wildlife Commission

The Mi'kmaq Fish and Wildlife Commission (MFWC) was established by the Assembly of Nova Scotia Chiefs. Its mandate is to manage all resources for the Mi'kmaq in NS. Several recent decisions have affected the Commission's work. In particular the Marshall Decision on September 17th has affected all agencies. The First Nation's concerns tend to be met with either a romantic view that things were so much better in the past, or a sense that things will change so fast that we may not get a piece of that action. The truth is in the middle. The Mi'kmaq have a high dependence

on the natural environment, particularly for wild meat, and negative impacts are felt at the family level when their food supply is impacted.

Since the Marshall Decision we have been working on an integrated resource management policy which takes a holistic approach and recognises individual harvesters as the units of integration. We see multiple resource use such that part of a person's income may come from the inshore fishery, part from the pelagic fishery, part from logging, etc. This reduces the risk of market changes undermining the local economy, or of the inappropriate actions of individuals detrimentally affecting the sustainable use of the resource.

With respect to the oil and gas industry, catastrophic effects are not our main concern. Incremental effects cause more anxiety because they can cause a shift in resource availability, affect harvesting, and displace activity leading to greater pressure on other more limited resources. The other concern relates to physical limits—the Mi'kmaq are just getting access to the commercial fishery and the last thing they want is for it to be limited by an increasing number of exclusion zones for oil and gas operations.

The next concern reflects the Mi'kmaq dependence on the natural environment for food, and thus focuses on bioaccumulation. We are working with McGill University to examine the nutritional value of traditional diet. Families that depend on a traditional diet have better health than those who rely on the non-traditional diet. However, contamination of the food supply could have a health effect in the population that is dependent on it.

Finally, more trust is needed and this will come from better communication. It is not enough to work with the Mi'kmaq bureaucrats or to send in reports. You need to spend more time talking to the people themselves. They will help to design a better monitoring program.

Inka Milewski, WWF Canada

The need for more rigorous, more meaningful and long-term marine environmental effects monitoring (EEM) will escalate as just about every square inch of ocean is being eyed for either oil and gas exploration, sand and gravel mining, mineral potential, or aquaculture development. And, just about everything that moves (or for that matter, doesn't move) in the ocean is thought to have potential for human consumption, animal feed, fertilizers, pharmaceuticals, or chemical additives.

Very soon we will have oil and gas projects adjacent to marine protected areas, adjacent to fishing grounds, adjacent to ocean dump sites as the federal government embarks on its program of integrated management for Canada's oceans. The lofty aim of DFO's integrated management is to co-ordinate the management of human activities in the marine environment. In reality, this means slicing up the marine environment and its resources among the various interests. If this is the case, the scope of environmental effects monitoring will need to go beyond the conditions and requirements placed on a single project, like SOE Inc., Hibernia, or Terra Nova. At any one site, there will be a need to evaluate the effects of multiple activities on multiple species on multiple ecological levels. In other words, there will be a need to do some kind of evaluation of the cumulative effects of all these activities on an ecosystem scale—a far more complex problem than monitoring discharges from an oil or gas well. The question is—who or which agency will have the responsibility to undertake this overall monitoring and assessment? And second, do we have adequate knowledge to undertake meaningful environmental effects monitoring at the ecosystem scale?

To answer the first question, clearly it should be the federal government and it should include the help and cooperation of the people who benefit from ocean resources. I know we could

have a lengthy discussion on exactly what this means—perhaps some other time. As for the second question, "Do we have adequate knowledge to do meaningful monitoring?", I think not. The reason is—as has often been quoted—"ecosystems are not only more complex than we think, but more complex *than we can think*". This fact requires us to be prudent, cautious and more conservative. It means we need to ensure that we put in place bigger buffers, not smaller ones. The error bars on our predictions should be large not smaller, and we should require the best that technology has to offer in term of decreasing discharges. As extraction of ocean resources—living and non-living—increase, history tells us we need to raise the standards for management, not lower them.

Before I pursue this last comment, I would like to back up and say a few words about the role of non-governmental organizations in environmental impact assessment processes—the process that decides what the Valued Ecosystem Components (VECs) are and, in turn, what is monitored through EEM programs—and advisory groups that oversee EEM programs. With respect to my colleagues at this table, I don't think any of us who represent non-governmental organizations have the knowledge (or are qualified) to fully assess the information brought before us over the course of this workshop, EIA panels, or advisory groups. In the face of overwhelming technical and scientific information, exactly what does industry and government think non-governmental organizations can offer when we are asked to participate in these processes and advisory groups?

The conservation community often believes it is only asked to participate so corporations and governments can be politically correct. They are also asked to participate by default—because the multi-stakeholder processes has become a cultural phenomenon. I want to hope and believe that groups like ours are asked to participate because of our specialized knowledge. For the World Wildlife Fund, it the science of conservation. However, unless conservation goals are explicitly set at the outset of the planning process, there is no sense in having us participate because we are very limited in our qualifications to fully assess the technical and scientific information that is presented.

It might surprise some of you in this room that a rigorous science has developed around the concept of "conservation". In fact, there are many peer-review journals such as Conservation Biology, Landscape Ecology, Biodiversity and Conservation, Biological Conservation, and Aquatic Conservation: Marine and Freshwater Ecosystems to name just a few. The kind of questions this science pursues includes: How much habitat is required to support a viable population of a certain species? What is a minimum viable population? What are the ecological requirements (such as reproduction and feeding) of a population or species? What effects do habitat fragmentation have on species interactions and survivorship? What are the temporal and spatial scales of natural disturbance regimes? We are interested in thresholds and we distinguish between management threshold and biological thresholds. A biological threshold is a point at which an irreversible change in a population or ecosystem may occur. Management thresholds are points at which the risk of reaching biological thresholds are unacceptably high. Since we know less about biological thresholds, we need to ensure that management thresholds have a sizeable margin of error.

So where does our knowledge fit into an EEM program that is about management not conservation. I know many of you would say that conservation is part of management but I beg to differ and this is why. The underlying goals of management—whether fisheries or environmental effects—are fundamentally different from conservation. Conservation biologists view the goals of conservation as maintaining evolutionary

potential (genetic diversity), energy flows through food webs, restoring trophic links, and maintaining biological diversity. Management, whether fisheries, environmental or integrated resource management, is human-oriented not nature-oriented. For example, fisheries management is about setting quotas, imposing gear restrictions and allocating fishing licenses—managing human activity—with the aim of having a sustainable fishery, not maintaining trophic links. In other words, management looks at how much can we take and conservation looks at how much do we need to leave alone.

Now back to my question—where do we fit into the process of environmental effects monitoring? Nowhere if, when the goals of EEM are being identified, conservation objectives are not part of those goals. We participated in the Sable Project public hearings precisely to ensure that conservation goals were taken into consideration. We took our case for conservation to regulators and to the public. An exclusion zone was established to protect and conserve the Gully and its resources. And, according to Hal Whitehead who specializes in the ecology of Northern Bottlenose whales, there appears to be no effects (at least behavioural effect) from the adjacent gas development on the whale population. Not only have the whales been protected, this conservation initiative has provided useful information regarding the effectiveness of buffers between areas with different management objectives. It has been a struggle to get these conservation measures and we are not out of the woods yet. A lot more oil and gas exploration and development is scheduled around the Gully and we do not know what the cumulative impacts of those activities will have on the Gully's inhabitants. I can only hope in the future there is less of a struggle to include conservation goals in management programs—whether environmental or resource management—than there has been in the past.

We need to raise the bar for management programs so that they truly include nature conservation. Raising the bar means including goals for biodiversity conservation which can be met through a system of representative marine protected areas. As the experts, we're telling you that this is what has emerged from conservation science, like it or not. No amount of management or assessment processes will change the fact that we need a representative system of protected areas to protect biodiversity. Let's set this as a goal, and then achieve this through management—which means that we all work together to make sure it is done equitably, reflecting everyone's interest.

On behalf of the World Wildlife Fund, I would like to thank the workshop organizers for asking us to participate in this forum.

Charlie Warner, Chair, Strait of Canso Fisheries Liaison Committee

In 1995, prior to the Joint Review Panel hearings, SOE Inc. established two Fisheries Liaison Committees (FLC). The Offshore FLC and the Country Harbour-Drum Head Fisheries and Aquaculture Liaison Committee. The Strait of Canso FLC was established later in 1998. The purpose of these three FLCs was to address the concerns of the fishing industries offshore, near Goldboro, and in the fishing areas near the pipeline crossing of the Strait of Canso. The two original FLCs, comprised of many local fishery representatives, provided valuable knowledge of the areas around Sable Island and the Betty's Cove region near Goldboro which was vital to SOE Inc. to identify the best pipeline route and installation technique. It also helped to establish an environmental effects monitoring program to ensure that the project would have a minimal impact on the fishing environment.

The three FLCs and SOE Inc. developed and were guided by the following seven principles:

- Both fishers and SOE inc. are legitimate users of the sea and the seabed.

- The purpose of the Fisheries Liaison Committees is to provide a forum for communication, education, and resolution of potential problems relating to project-fishery operations. The goal is the successful co-existence of commercial fishing, aquaculture and the Sable Offshore Energy Project.
- The SOE Inc FLCs will provide basic information for SOE Inc. and its contractors regarding the operations of the commercial fishing and aquaculture industries so that project planning and at-sea operations may be carried out in ways that avoid or at least minimize potential conflicts with fishing and aquaculture operations.
- The SOE Inc FLCs will provide basic information to the commercial fishing and aquaculture industries on the schedules, operations, equipment and techniques as well as a SOE Inc. contractor list to help commercial fishing and aquaculture industries communicate with responsible parties in order to avoid conflicts.
- SOE Inc., its contractors and the fishing and aquaculture industries, will offer suggested voluntary guidelines to each other for project planning and marine operations in order to minimize inter-industry conflicts through effective and early communications between industries.
- SOE Inc., its contractors, and the fishing and aquaculture industries will make an honest effort to avoid conflicts in their at sea-operations through mutual avoidance and mutual protection.
- Compensation will be a means of last resort and be applied only when other means of conflict resolution fail. The approach will be fair, rapid and voluntary, enabling the fishers/aquaculturists to resume work as soon as possible, no worse and no better off as a result of SOE Inc.

The Strait of Canso FLC is composed of five fishing representatives, one First Nations representative, and a member of the Sable Advisory Group of Guysborough. The meetings provided a forum where the fishers could raise concerns regarding the crossing of the Strait. We provided SOE Inc. with information on the fisheries, aquaculture sites within the Strait, potential sensitive areas, anchorage, underwater cables and shipping in the area.

The Strait of Canso FLC registered the following concerns with SOE Inc.

- the nature of contaminants
- the types of monitoring to be used
- the methods of construction used for the Strait crossing
- the scheduling of the pipeline crossing
- local employment of fishers during construction and monitoring phases.

The concern about contaminants largely focussed on the possibility of disturbing contaminants that have accumulated on the bottom of the Strait during heavy industrial activity over the past 30 or 40 years. Samples were taken of these sediments and the results made available to the FLC for review. The marine geotechnical company that did the sampling was on hand at one of the meetings to discuss the results of their sampling. Representatives of NS Department of Environment and Fisheries and Oceans were also on hand to review the results and answer any questions from the fishers. While a few samples were slightly above acceptable levels, it was determined that the level of contamination did not represent an environmental problem as long as the area was not trenched.

The three possible methods of crossing were also reviewed with fishermen:

- directional drilling (preferred by fishermen)
- trench (preferred by SOE Inc.)
- bottom lay protected by armour stone.

The bottom lay method was chosen because it

represented the best balance among construction costs, physical security for the pipeline, and reduced potential for environmental impacts. A monitoring system was established to document sediment dispersal during construction and post-construction. Local fishermen were employed to transport the monitoring crew to sediment sampling sites. Fishermen were also invited to observe sampling procedures as well as armour stone dumping during laying of the pipeline. Scheduling prevented the pipeline from being laid during the fishing off-season between November and April, and local fishers agreed that the pipeline could be installed between May and August. Two local fisheries were affected by this schedule and fishers agreed to remove their gear from the water. Compensation agreements were reached and the project proceeded on time.

What was achieved? It was a very informative and educational experience for many local fishers and a lot has been accomplished through their involvement with SOE Inc. Fishers were able to deal directly with SOE Inc. representatives and mutual trust and respect developed between the industries. Continued consultation with SOE Inc. is expected to be maintained throughout the life of the Project, and FLC representatives participate in the SEEMAG advisory group. The FLC forum has provided fishers with ample opportunity to present their views and these have been addressed accordingly. The FLC was kept up to date as the project progressed and decisions were finalized. In the Strait of Canso in particular, we have seen the negative aspects of industries over the last 30-40 years as well of negative effects from the construction of the Canso Causeway linking Cape Breton to Nova Scotia and also on the fishing industry environment. In the past decisions were made without much consultation. It has been reassuring to have a company like SOE Inc. working so closely with the fishing industry and seeking advice on monitoring programs.

From my position on SEEMAG, I have been impressed by the amount of monitoring work that has been completed on the Sable project, and the plan of work still to be implemented. A lot has been accomplished, and we have had a lot of good ideas on ways in which the fishing industry and the petroleum industry can share the sea. However, while the environmental effects monitoring that has taken place during the Sable project has been intense, I believe it is too soon to draw conclusions about the effects of the hydrocarbon industry in sensitive fishing areas. SEEMAG should also review the significance of the Gully and the reason it has become a protected area. We cannot assume that this is the only area that needs protection.

As a core fisher I feel I must comment on the issues in the news with regard to the CNSOPB. Some fishers have accused the CNSOPB of being a promotional agency for the oil and gas industry instead of acting as a neutral regulatory authority. Exploratory leases were issued without first consulting local fishers and now the fishers want further issuance of licenses to be halted until a full environmental assessment of waters off Nova Scotia can be completed. They are concerned that exploration activities will cross important migratory routes for ground fish and pelagic stocks such as herring, mackerel and tuna. These stocks are vital to the survival of coastal communities. Considering that I am one of many thousands of fishers in Nova Scotia, and depend on the sea for my livelihood, I am concerned with what seems to be taking place. I believe that both fishers and the petroleum industry are legitimate users of the sea. But a successful co-existence can only be established if we can determine that the fishing industries will not be adversely affected along with the thousands of people who are directly and indirectly dependent on the fisheries for their livelihoods.

Brian Giroux, Scotia-Fundy Mobile Gear Fishermen's Association

I represent a group that fishes in the offshore area. This industry has been a mainstay of this province for several hundred years. To get some perspective of the experience of our industry with oil and gas over the years you have to go back to the activity in the 1970s and 1980s. At that time people were using live explosives for sonic sources, and they were not necessarily concerned with some of the things that we now know are very important. A rather "poisoned" relationship developed at that time, in large measure caused by the attitude of the oil and gas industry regulators. When COGLA proposed some of the leases and people from the fishing industry went in to talk about their concerns about sensitive fishing areas, they were told—in essence —"Trust us, we know what we're doing". On further investigation, it became clear that the benefits of the petroleum industry were being promoted without a clear understanding of its impacts. Not every study needs to be replicated, and not everything needs to be measured and tested, but there are issues to be examined.

More recently, the regulator has become more consultative, although I still share the concerns of some of the other panel members about the process involved. It should be remembered that the fishing industry has its own interests to protect as well. Excellent harvesting areas are special places from a fishing perspective, and we do not want them to become inaccessible, either through oil development or designation as Marine Protected Areas (MPAs). We consider their location to be proprietary information that belongs to the fishing industry. Knowledge of a good fishing area is a valuable resource to fishers who make their living from the sea, and they are not willing to give it up.

In many cases we can prove that an area is consistently productive. There are places in the ocean where you can catch fish time and time again. So far the petroleum industry just hasn't moved into the productive areas (many of the areas affected by SOE Inc. are essentially unproductive). Currently, we are attempting to deal with the areas we want to protect through the concept of 'special places'. This means that when a lease area is identified we try to identify the most sensitive portions and then discuss restrictions to control the environmental effects of exploration activities.

The current approach used by the regulator has led to a better working relationship, but there is still room for improvement and we have to build some new bridges in terms of trust. In the future we can deal with these things in two ways: in the macro sense when we get information about where people intend to operate, and in the micro sense when there is a specific proposal.

To some extent I am still uneasy about the way it happens at the macro level; it seems to put the cart before the horse. There are still some problems. For instance, when a seismic company is out there doing a spec shoot they may not want to say exactly where they are or who they are working for because other companies are out there as well. I can understand that leaseholders want some confidentiality, but those of us who are trying to deal with the interaction between the industries can be sworn to a confidentiality agreement. We really should deal with them in advance. If we don't, we will just continue to argue about everything or the process will continue to be subject to objections.

We would like to look at the future of EEM studies. This can incorporate the macro and micro approach since there are big and small issues to be addressed, some of which may well be resolved. It is important that this information feeds back into the regulatory regime so that, if we answer questions to a certain level of confidence, we can move the regulatory bars a bit. I think that it is also true when it comes to studies in the field. For instance, it was mentioned yesterday that when the

pipeline was coming ashore, sediment targets were set. With a sediment target in place, when you see samples exceeding a threshold level of acceptability, you can shut down the activity or do something else about it. There are things like that which can be built into these studies to provide a quicker response because regulatory regimes are largely dependent on voluntary compliance.

There is not a lot of field observation of proponent's activities. I've had difficulty finding numbers. You hear of an incident, then 200 barrels turn out to be a couple of cupfuls. When a voluntary reporting system is in place, people may try to get away with it and take chances—and I can see why people in this industry might do that. Feeding a bit of effort back into the field work may help to get these things working better.

I certainly agree that the future lies with some of the cumulative effects issues. With all of these activities going on, we have to start looking at that. Also, right now in our industry we are being strangled a bit by the precautionary approach. Everyone wants to add another measure of precaution, and if you continue to do this you end up with your hands tied. I think it's appropriate to apply the precautionary principle, but I think it has to be applied at just one point and not allow an unwieldy process to become a cumulative effect itself.

Discussion

Chris Milley

We must remember that the First Nation in Nova Scotia has a title interest in both the land and the sea bed. So when we monitor the environment it is important to consider that what we are doing is monitoring change that is of concern to both Nations. It is no longer a pristine environment, and we want to understand the scope of what we have to manage jointly in the future.

Unidentified Speaker

This question is for Mark. Do you believe that industries other than the oil and gas industry should be required to put into place the kind of programs that we have heard about in this workshop. For instance, if you applied similar criteria to the fishing industry would you require that they provide volumetric and chemical analysis of anything that went overboard from any fishing vessel? Would it be a requirement that measurement of sound from idling fishing vessels as well as vessels in movement be monitored? Would it be a requirement for changes to government or private wharves involving pile driving or construction activities on land to be monitored 250, 500 and 1000m away? In other words, should this effects monitoring approach be applied to every industry and not just to the oil and gas industry?

Mark Butler

We should maintain the standard that the oil and gas industry is subject to and it should be extended to other industries. A lot of money is spent on environmental effects monitoring so we should make sure the money is spent well. As part of this we should be looking at the big picture—energy conservation, renewable energy, climate change and air pollution . We have been pressing some issues with the fishing industry, such as use of gear and marine discharges, but if fishing is done right, the industry will be with us for the next 100 or 1000 years. However, we know that some day we will be phasing out fossil fuels. While you can say that natural gas is more attractive than other fossil fuels, it can also be seen as the coal industry of the future.

Brian Giroux

The oil and gas industry has a lot of concerns in common with the fishing industry and I have some sympathy for them. The fishing and oil and gas industries are jumping through a lot more

hoops than people think. However, you have hit the nail on the head. I have been looking at coastal zone management issues for years. We ask people involved with the oceans to do incredible things, but what we do on land is just stunningly negligent at times. I'd certainly like to see more environmental assessment of highways or suburban developments. Why don't we redevelop the core of urban areas instead of allowing habitat to be paved over for single family houses?

Don Gordon

Many of us in this room were involved in the Sable environmental assessment process a few years ago. At that time the WWF and Ecology Action Centre brought forth some important issues. As a SEEMAG member I would like to ask if you feel that the major issues have been addressed adequately, or are there still gaps to be addressed in the future?

Inka Milewski

The WWF became intervenors because we were concerned that potential marine protected areas would be foreclosed when the Sable project was approved. Our main concern was for the Gully which is an area that had been identified by a number of federal agencies as being an area of national conservation significance. So here was a project that could impact the ecology of the area and compromise its ecological integrity. During the hearings we did not undertake a critique of the fine points of oil and gas development but, based on what our scientists tell us, we felt that noise and discharges could travel and reach the Gully. We wanted to make sure that there was a sufficient buffer to protect the inhabitants. That was our purpose. We couldn't participate more beyond that. The science of conservation is rigorous but is not always part of the assessment process, and we wanted to make sure it was integrated into the assessment process in this case. We have been criticised for 'pushing' the Gully, but it had already been identified so we made sure that it was taken into consideration.

I would be concerned if, down the road, we confronted a situation where once again conservation goals were not integrated—goals which government has established in policy. Right now a management program is about to be implemented by DFO and I don't really see any provisions in it for conservation, and particularly for setting aside marine protected areas. As for our participation, it cost a lot of money to get government to do what it was supposed to have done in the first place, which was to ensure that those areas that had already been identified were protected. It should have been right up front in the EA that the Gully was off limits and this issue should not have been up for debate.

Mark Butler

The issuance of all these licenses on the east coast of Nova Scotia from Georges Bank up to the Laurentian channel has a real implication for the MPA process. What will happen in 15 years time? We were told during the EA process that 'we can only look at this project in this forum' you can't talk about future projects, but it a bit ironic that the oil and gas industry can get up and say 'this is the first of many projects' and yet that thinking is not carried into the rest of the deliberations.

With respect to the adequacy of the environmental effects monitoring, the program came out for review after the hearings. As Inka mentioned, we do not have the capability in-house to undertake technical review—statistical analysis, for example. However, in that case, Trevor Kenchington did review it for us and concluded that the plan was unacceptable. DFO also reviewed the first environmental effects plan put forward by SOE Inc. and found it had problems. These comments were made public—an important point—and as a result the first plan was rejected. The proponents then improved their

program.

John Candler, MI Drilling Fluids

Mark commented earlier that the 'solution to pollution is dilution', and that after six months pollutants may appear to have disappeared but questions arise about where they have gone. That is not the mechanism that the industry is relying on. The solution to pollution on the industry side is source reduction. At SOE Inc. they are using some of the most advanced technologies available. You can now see contaminants going back to background levels in six months, while in older projects it may have taken 10 to 15 years to recover. This has been tracked using environmental monitoring and represents real progress in a few years. There have been other advances which have enabled pollution to be cut to a very low level and additional technical development will further reduce those discharges. The overall goal needs to be continued improvement, with industry, the government and NGOs working together. Good decisions are based on good science, so focus the research on the cause and effect mechanism and use it to develop new and better technology. There has been a lot of good information presented in this workshop. We need to use it and work together rather than draw battle lines.

Mark Butler

The petroleum board has said that there will be no discharge of oil-based muds from the beginning of 2000, and that there have be improvements in technology. But my basic point is that while we are all aware of the oil industry when we can physically see its infrastructure, at the edge of the Shelf it is out of sight and its effects are 'taken away'. Maybe the oceans are big enough to absorb the discharged hydrocarbons—and some heavy metals—but surely the basic management mechanism for some of those discharges is still dilution. And when we talk about getting back down to background levels in a given time, it sounds like dilution is being used as a management mechanism for at least some discharges.

Slawa Lamont, UCCB

This is a question for Inka. You were talking about conservation versus management, and you clearly have problems with the way the management fails to recognise the goals of conservation. Would you like to see a strategy to integrate conservation into management since we cannot afford to live without either one of them?

Inka Milewski

I'll pass this on to Chris Milley.

Chris Milley

We work under a system that has a different spiritual and cultural relationship. The Mi'kmaq management system is one in which humans are part of the environment, or natural predators. The Mi'kmaq management system is called Netukulimk. It views humans as part of the ecology. Conservation is not the objective but it is the foundation on which you manage. If you look at fisheries management or most other natural management systems in Canada, the foundation is economic exploitation and the fundamental question is how much can we use and how far can we go before we have defeated ourselves by taking too much from the future. Netukulimk is a very different approach. It is time we started looking at alternative systems like that as being mainstream.

Inka Milewski

I would concur. Our economy is built on our resources, rather than the other way round. And if we want to operationalize this word 'sustainable' then, when we are dealing with renewable resources, we need to ask ourselves what we should conserve in order for them to be there in the future. Conservation goals that I talked about,

such as maintaining trophic links and biological and genetic diversity, are not achieved by allocating licenses, quotas or gear restrictions. Those are not conservation tools, they are human management tools. So when we try to integrate conservation into management we have to identify our conservation objectives. In fact the federal government has done that, and to maintain biological diversity the federal government has said that it is going to set aside a network of terrestrial and marine protected areas for conservation. So, if that is the goal, we must find a way to fit it into management.

Slawa Lamont

Are you calling for redefinition of 'economic profit'?

Inka Milewski

We could get into a very long discussion about valuing ecological functions and processes and non-commercial species. People have tried for decades to do this and have not been very successful so far. On the other hand, we have an imperative to act on an existing conservation policy. It has to be done right now at this time of escalating development, so we can't get bogged down in the other, more academic, discussions.

OPEN MIKE DISCUSSION

Where do we go from here?

***Dr. Ian McLaren**, Dalhousie University, Moderator*

Ian McLaren

A question for Jim Ray. Presentations and questioners yesterday indicated that the effects of development on individual environmental components in time and space will be minor or negligible, but the question continually arises "What about the cumulative effects?" This is a difficult question but perhaps we can use it to start the discussion.

Jim Ray

Cumulative impacts are very difficult to study. In the years we have been looking at this issue, we have run up against the limitations of the science we apply. At present, we can make certain measurements, and certain biological assessments, but we are not close to figuring out cumulative effects. There are 3500 structures in the Gulf of Mexico — that's a lot. The ongoing monitoring, undertaken in various programs, concerns the contamination of different biota, the impact on commercial fish species, and sediment contamination in the Gulf of Mexico. Our environment is depositional with very fine grained sediments which are great for accumulating junk. If there is contamination, it will be found in the sediments. They are good from that viewpoint—provided you get away from the Mississippi River which confuses and masks everything.

A few years ago when we were finishing up the produced water bioaccumulation study, we ended up doing the survey that I briefly mentioned this morning. We took samples from areas in the path of the Mississippi River where there are many platforms and a lot of discharges. These are shallow water areas where there is not only river influence but where there is also re-suspension and transport which continually stirs up the bottom and puts materials back into the water column. I didn't want to do that part of the study because I didn't know what I would find, or how to interpret it. But the good news was that in the

molluscs and fish we examined, the levels of the target analytes were very similar to levels we had seen in deep water in remote locations. I would have never bet on these results and in a way, that represents an indication of cumulative impacts.

Otherwise I do not have a magic way to measure cumulative impacts. As you develop your plans for future monitoring programs, your activities will be dictated by the limitations of the science, and your ability to measure and to interpret what you are getting. The biggest problem of all, no matter what kind of activity you are assessing—oil and gas or fishing, is your ability to collect population level information and interpret it. This is very difficult.

Percy Haynes, Fisherman, Gulf of St. Lawrence

The presentations yesterday dealt exclusively with the offshore and not with anything in sight of land. Was this by accident or design? It seems to me that oil and gas exploration is one big experiment. No-one has any real answers for what will happen in twenty years, but everything is going ahead nevertheless. On the Cape Breton shore, Parcel 1, there are very rich fishing grounds, 690 fishermen live on the coast, and in the southern Gulf of St Lawrence there are 3300 licensed fishermen, and a billion dollar industry.

One day we found that an oil exploration permit had been issued within our fishing grounds. If people really want to build trust and work well together, then Parcel 1 should be withdrawn, and a proper process put in place which includes an environmental assessment, and impact study, and a review panel to look at the whole situation. If we want to have sustainable development we need to look at what we have now. Sustainable development does not all lie in the future, it requires making the present and future work together. I don't see this happening right now. We were told that there will be seismic testing in September this year, and that we should be satisfied with the ESRF study which is basically a literature search of what has already been done in the Gulf. No work has been done anywhere in the world on seismic testing and lobsters, and there is no proof one way or the other what seismic testing will do to lobster larvae or most groundfish.

Oil representatives say that seismic exploration only kills fish within 2 or 3 metres of the cylinder. They don't like to tell you that there are up to 20 cylinders being towed in a grid and every 12 seconds these grids are firing, mile after mile, day after day. Anywhere we look world wide, seismic work has been followed by a downturn in the fishery. There are very valuable fisheries on the East Coast of Canada that mean a lot to the people who live in the coastal communities and there is no way that we can just back out of this and let the oil exploration happen on our fishing grounds. If you think that we are going to lay down and let this happen—forget it. You can't just come here and show pictures of what is happening way off the coast and not even talk about what is happening along the coastline. If you want to work in good faith and develop trust, withdraw Parcel 1 and put in place a proper process that will address the needs of the people involved in the conservation of fish.

Bob Helleur, Memorial University of Newfoundland

My background is in marine chemistry. The question is: how are the contaminants transported to the marine ecosystem? Has the microlayer, which is a very dynamic interface with atmospheric input, been studied on a continuous basis off a rig?

Jim Ray

None of our work has focussed on the microlayer. There has been some other work, and early information I have seen indicates that the concentrations found there were not high enough

to cause concern. In the States this question has been looked at but never pursued as a significant issue.

Bob Helleur

My other question relates to the fluff, which is a great food source for the benthic community. There have been some interesting studies on it. Do you feel that the sediment cores should be sampled to include fluff?

Jim Ray

I found the discussions yesterday on the benthic boundary layer to be very interesting because it showed some of the differences between our regions. In the Gulf of Mexico it is hard to tell when you have hit the bottom because there is a very soupy interface—a nepheloid layer that can be up to 10-15m thick, and has a high level of suspended solids and near zero visibility.

The questions that arise for me about your benthic boundary layer are: How thick is it? What kind of particle movement is occurring? What kinds of materials do you find in the layer and what are their concentrations? Those are the key issues. Looking at the information from scallops and other filter feeders, the question is—if you have a thin layer near the bottom, how dynamic is it, what is in it and in what concentrations, and how does that fit into the suspension and transport mechanism. Again you are in a much more dynamic environment than we normally work in so a lot of the things that happen are different. You've go these light flocs but you also have some pretty good bottom currents that can re-suspend material up to sand particle size.

Ken Lee

In the preliminary results of my study of produced water, we found that contaminants may be transported to the surface with dispersed . We will be looking at that in the coming year because it was a new finding. We will be looking at the potential transport of both dissolved and particulate contaminants to the surface microlayer. In terms of the impact of the floc near bottom, on the BIO cruise last year, we did collect samples of the BBL for radionuclide measurements. We can use Pb^{210} as a tracer for particulates so we will look to see if we have particulate material coming from the produced water contaminants into the BBL. We will also be undertaking chemical analysis for metals on those samples.

Jocelyne Hellou, DFO

I would like to speak as a citizen rather than a research scientist and comment on the workshop. I think it is a very good first step in having open discussions about Sable, Terra Nova and Hibernia. I would also like to comment on something that Jim said in his presentation—that this workshop cannot cover all the science that has been undertaken, it can only cover a few things. However we are making a good effort at discussing the state of the environment. I would also like to complement Hibernia, Terra Nova and Sable people who gave presentations about the EEM approach. The best that can be done at this stage of our knowledge is to include some chemistry, some toxicology, and some biology. We have to remember that science is in dynamic change and we can learn from around the world. Canada cannot be isolated. It almost seems as though there is more communication between the people in Hibernia, Terra Nova and Sable than between people in DFO! We should learn from that.

I would also like to comment on a small item in Jim's presentation. He said that there were no human health effects. I suggest that there is not very much known about the link between PAHs, hydrocarbons and human health effects. It is a major research topic. Other than that I find that this workshop is a good first step, others are needed but this has been a good event.

Elizabeth May, Sierra Club of Canada and Dalhousie University

It is encouraging to have an open forum on the issue of offshore development, especially since we have had none at all on the matter of exploration and development in the southern Gulf of St. Lawrence. For that reason we need to use this workshop to raise questions about what we do and do not know about the ecosystems in shallow coastal waters as opposed to the offshore.

This workshop has focussed on a reductionist examination of drilling wastes and other produced water impacts, when the whole chain of oil and gas production, as pointed out by Mark Butler, has very broad and even global impacts that go well beyond the specific localities where they are taking place. We don't have very good data about the impact of offshore fossil fuel development. As we move closer into coastal waters, that information gap is still there but we have greater potential for human health effects because these areas are much nearer to the coastline.

Since we are barrelling ahead, and are looking at EEM as we go, I wonder if we need to bring in the precautionary principle much sooner in areas like the southern Gulf of St. Lawrence. After all, when it comes to seismic exploration we have a lot of information to suggest that there will be significant impacts on the existing fishing industry. Data gaps also exist and are really significant for commercial species like lobster. For non-commercial species we know very little. How can we take these risks when we know that the global situation for the world's oceans is not particularly good. We have dying oceans and collapsing fisheries. And yet in an area where we have a sustainable fishery, and other biological diversity and wealth, and healthy communities in the southern Gulf of St. Lawrence, we are essentially proceeding in the absence of knowledge in Parcel 1 to pursue both seismic and potential oil and gas development. So where are the voices of the scientists in the fisheries community who know where the data gaps are and who must be concerned that we must be taking a very large risk with the health of our ocean communities?

Roger Green, University of Western Ontario

I've been thinking about cumulative effects and my comments are largely philosophical. When most people talk about cumulative effects they really want to know what is going to happen in the long run. History tells us that you can find examples of both benefits and losses from human action. Obviously the cumulative effect of hunting on the passenger pigeon is that they are now extinct, and there are many similar instances of irreversible harm. You can find the opposite examples too, where some potentially bad situations have been found to be reversible—such as the reforestation of the northeastern United States which is now probably more forested than it was when the Europeans arrived. What happened is that the farming moved west.

While I know that people in the NGOs have been emphasising cumulative effects, I also know the limits of the technology and what we can do. I think we need to try to determine, in terms of risks, which things are reversible and which aren't. The situation with the northern cod is uncertain. If it does come back, we will have learned a lesson. I was involved in the *Exxon Valdez* work where there was a lot of concern about oiled sea otters and bald eagles, but what really matters is whether any species populations were knocked out and won't come back. The real question when we study cumulative effects is—are we risking doing things that will have irreversible effects? That is what matters most.

Slawa Lamont

I want to come back to the question of measuring cumulative effects, and I want to direct a question to Jim. You said that we cannot measure cumulative effects very well because of the limitations of the science. Could you tell us,

from your background and experience what kind of science should we do and in which direction should we go in order to assess cumulative effects?

Jim Ray

In the next 10 years our ability to make chemical measurements will improve. We can already detect chemicals at very low levels, so that is not what limits us. I believe that examination of population level effects is one of the keys in looking at cumulative impacts. But one of our biggest problems is being able to find out where the marine organisms are going and what they are doing. There are species for which we do not have full knowledge of their life cycle, for instance. So right now we are not able to see any acute effects or chronic exposure effects, which are early warning signs of problems.

The comment was made previously that this is all a big experiment. If so, it has been going on the last 40 years or so. Offshore oil and gas development is taking place in many parts of the world. It is being studied in all those places and a lot has been learned. We have many years of data but the tools and methods to address the cumulative issues in the marine environment seem to be lacking. I'd be interested in other people's ideas on this matter.

We do know that we need to measure cumulative impacts continually, not only for this industry but for all industries as we go along. We have a few fisheries in the Gulf of Mexico too, including a large shrimp fishery. There are concerns about that as well since the catch figures go up and down. The drilling waste goes into a benthic environment. Much of the shelf is very shallow there and our shrimp are just walking back and forth through it all and their feeding seems to be unaffected since there are no big impacts on the shrimp fishery or contamination of the shrimp that we can see. Also, where does most of the spawning and early life stage growth occur? In our wetlands and estuaries. I would not hold up the wetlands of Louisiana as a shining sign of environmental purity. Oil and gas development started there 40 years ago. They drilled all through it, there are pipelines all over the place, there has been erosion, and many wells were drilled in shallow low energy environments. Most of that has stopped, now that there is no discharge permitted in most of those areas. However, given the way things were done 40 years ago, when discharges were occurring in one or two metres of water right into the spawning grounds of a lot of our fish species, if degradation was going to occur you would have expected to see it there, but there has been no degradation of these fisheries. Much of this is anecdotal but it still can't be ignored. Now we are smarter, discharges have stopped in the inland waters and bays, and what we discharge today is a lot different than what we discharged 10 or 20 years ago. Some of that is because of what we have learned through scientific inquiry and some because of the regulations we must now follow.

When we first were subject to regulations on the composition of water-drilling muds, we looked at the composition of drilling muds. We found that you can certainly kill crustaceans with diesel oil—it doesn't take much either. Big surprise. However in water-based muds, potassium chloride muds (KCl) will also knock out crustaceans so we stopped using KCl. In other words, when toxicity limits are put into regulations you find out very quickly what can and can't be used because it affects toxicity.

Don Gordon

One way to enhance the examination of toxic effects is to put more emphasis on the biological parts of an EEM program rather than on a chemical analysis. Using a biological approach (organism) you can look at the effects of a number of contaminants that you may not know are going to manifest as a physical effect. So I see value in

using methods such as shell fish moorings where you can put an organism out and look beyond the accumulation of a particular contaminant to the effect of whatever is present on the growth and feeding of the organism.

In addition, with respect to baseline studies, Jim emphasised the need for reference sites and I agree with this completely. It is essential to record the substantial natural variations that we know take place in space and time. However, it is also important to have certain baseline studies in the EEM programs particularly with respect to the benthos and benthic habitat which we know has a lot of spatial variability but which can be quite stable on a temporal basis. As Brian Giroux said this morning you can often go back to the same area of the sea floor repeatedly and find the same types of structures. It is very important that we have good baseline information on benthic habitat and one initiative that we are trying to push here at BIO is a very bold program of mapping our entire continental shelf. It is called SEAMAP and the concept is to map our benthic habitat over the next 25 years using the wonderful tools we have here in Canada such as the multibeam bathymetry, various geological tools, and video and still photography to identify the organisms. We need this spatial baseline information of benthic habitat of our entire marine area as the basis for any type of management—be it for fisheries, oil and gas, or for identifying the best areas for Marine Protected Areas and other activities.

The other point I'd like to make goes back to the comment about the scope of the workshop. Please bear in mind that it was organized by SEEMAG specifically to look at existing EEM programs in the offshore. We did not set out to ignore inshore issues, these are very important, must be looked at and hopefully can be examined in future fora. It is not clear to me who has the responsibility to take the lead to set those up. But some very important meetings should take place to address issues such as inshore exploration.

Jocelyne Hellou

We need a balanced approach to environmental studies which is multidisciplinary. We can't just look at the biology without looking at the chemistry around it. The ocean is a dynamic environment, and it cannot all be monitored. Sometimes the biological information is ambiguous, but with the addition of the chemical component another dimension to your information exists and this assists the interpretation in a less biased way. You don't always need statistics to interpret things, you just need relevant information.

Ulrich Lobsiger, TrisMar Research Incorporated

I am a private sector oceanographer and instrument developer. We have heard a lot about how dynamic these offshore environments are. We have also heard that while we know a lot, we still need a lot of knowledge. This morning it was re-emphasised that technology and science are not well enough developed. On the other hand there is also a consensus that from a practical EEM point of view we probably do OK. With reference to the 'conflict' between biology and chemistry, I feel that the HABITRAP approach and visual recording are technologies that can give us useful information on the dynamics of the system and if we tie that information together with chemical and physical parameters we can learn much more. Though in the shelf environment we may be doing OK with EEM, inshore will see much more resource development in the next 10-30 years. Maybe there is an opportunity to push these new methodologies to gain an understanding at an ecosystem level. Then these arguments about what is better, biology or chemistry, become replaced by a greater understanding of the ecosystem in general.

Jim Ray

As you build information over several years

and from many different places, it is very important also to make use of the latest knowledge of ecological risk assessments and human health risks. Put the science to work to assist with the risk decisions; it can't just be done on perception.

John Candler

Science often does not allow us to draw absolute conclusions about whether something is good or bad. However, when you layer science on top of a regulatory process or onto the introduction of a new technology, you may no longer have the opportunity to avoid conclusions because you have to make a decision. All of the previous presentations have been on EEM. Trying to make regulatory decisions based on that information is rather like trying to drive a car by looking out of the back window. It does not necessarily give you the best information to guide decisions. So, I'd like to ask Cal and Jim how field monitoring studies and lab studies should be used to identify the technologies that will work best to minimise environmental impacts and to support decision-making in the regulatory process.

Cal Ross

I'd like to refer to the approach that has been taken here at the Bedford Institute of Oceanography. You start with lab studies which are relatively quick and cheap and develop models once you have determined what is going on. You then follow up with field verification. For example, Peter Cranford showed how he took his lab results, put them into the bblt model, identified areas of potential impact and will follow up with field studies to see how accurate those links are. That is a cost effective way of approaching the problem.

How does that sort of investigation fit into the regulatory context? The regulator does not have a comfortable position. Regulatory decisions cannot be made strictly on the science. He or she has to balance political, social, and economic considerations as well as scientific information, and come up with a rational regulatory regime. Some of the biggest problems arise when information is taken from areas with a different societal context, a different receiving environment and many different influences, and is applied to another context. It is sometimes right but often wrong to do this, and the regulator can't rely on people in other places to come up with the right answer.

Jim Ray

Most scientific reports conclude with the words—more work is needed. At the Calgary drilling mud conference in 1988, I reminded the scientists in the room that the regulator looks to them for information to make decisions. And if he doesn't get the information he needs he'll make the decision anyway. It is the same here, you never have the definitive answer, you always need more information. What you have to do if you want to have a good balanced process is to provide the best scientific information you've got, make sure the regulator understands what it means and in that way he can use the best available science in his decision.

Irene Novaczek, Save Our Seas, PEI

I'm working with others in the southern Gulf region trying to understand what the implications are of oil and gas industry coming into this fishing area. I want to thank BIO for hosting this forum.

I met with my colleagues in the Save Our Seas coalition last night and we reviewed our perceptions of yesterday's reports and we concluded that despite encouraging noises from the front of the room saying that there is little to be concerned about, we were not reassured. For me it is tied to some of the attitudes that I saw being expressed. One being the glee with which the toxins were reported to have disappeared. Sorry, but in the ocean there is no such thing as

'away'. The other thing was inappropriate comparisons between the potential impact of an oil rig and, say, a grossly polluted river and its influence on an inshore marine environment. This other area of pollution does not legitimise the addition of new releases of pollutants on the grounds that other releases are larger.

I encourage EEM practitioners to look more at the big picture and to show that you are aware of and concerned with these larger issues. As you describe your latest gear, remind us that you are rational people and you see the wider issues. That would build trust and the potential for collaboration in the future.

I support Don Gordon's proposition of using biota to give us a 'heads up' indication that something may be going wrong, though we may not know exactly what component we should be looking for. If we find that everything we are testing for is at levels that should not be causing problems, tests such as the mixed function oxidase analysis may help to refocus the monitoring into something that is more appropriate.

I would like more information on flaring in the marine environment. We have heard nothing on the pollutants that are released during flaring. Perhaps there is no time now, but we would like more information. We want to learn more. We also want to hear some discussion of what happens when you put a rig in an environment that is much shallower, where there is a very significant thermocline which might have a significant impact on the propagation of sound or the movement of pollutants. What happens when you have an ice cover in the winter? Where do we go for information on the interactions in shallow water with lobster and crab habitat and also the problems and issues that arise in EEM in a low energy environment in which there is no large dilution and dispersal mechanisms, and smaller wave effects.

Mike Coolen, SOE Inc

On the matter of flaring, specifically on SOE Inc.'s installations, we started looking at this early on during the environmental impact stage. We model what we expect from flaring, and also put environmental health studies in place to verify our predictions. I would be glad to share what we have learned from our industrial hygiene analysis of what happens during flaring. Our goal is to make sure there are no impacts on our workers or our neighbours.

On the other matters, others may be able to respond, but there is a lot of information on drilling in shallow and ice infested waters. Certainly the near shore EEM program that Sable put in place will shed light on some issues, for instance lobsters and noise. It was related to pipeline construction but many of the pathways and the information are the same. That information is available publicly.

Cal Ross

This meeting was not set up to address nearshore issues, but we can get it to you if you leave contact information.

John Hall, Baroid/Halliburton

There is also some very good information on the web. The Oil and Gas Producers Association (UKOOA) web site and others have some very useful information. They have been very aware of these issues in Europe, especially in the Netherlands and Denmark where there is a great interest in environmental issues. The opposite viewpoints can be found in sites such as those of Greenpeace and others. The industry should also look at these sites to see what questions have been asked globally.

John Candler

With respect to 'disappearance' of contaminants, a great deal of money has been spent on monitoring the concentrations of

hydrocarbon contaminants in the environment. When base fluid contaminants appear to disappear, and while all the mechanisms at work are not entirely clear, one of them is certainly biodegradation. The new fluids are designed to do the job required during drilling and when they are released into the environment to degrade into non-toxic substances quickly. So it is possible to drill the well and have a minimal impact on the environment.

Drilling rigs are very visible structures in the nearshore environment. If there are problems in the receiving environment it is tempting to assume that they are directly related to the presence of these structures and the oil and gas industry. Previous discussion of other stressors on the environment has underlined that even though you can't see them, they are still there. Even if that rig were to be removed, that stress may not be removed. We need to allocate resources in a proportional manner according to what needs to be fixed. If you spend all your money addressing a very small part of the pollution, when that same money could have gone to reducing the majority of the pollution, the best job might not have been done under the circumstances. We need to ensure that when money is spent on protecting the environment, it is spent wisely.

Certainly the impact on tourism needs to be examined. Not all people dislike seeing rigs, some find them interesting, and they certainly attract fish and are the best places to go deep sea fishing.

André d'Entremont, CNSOPB

Speaking without my CNSOPB hat on, I want to make some comments on the matter of exploration in the Gulf of St Lawrence. I have sympathy with the Save Our Seas coalition's concerns but I am the only member of the environmental section of the CNSOPB and this position is very lonely. There are overlapping jurisdictions in that geographic area, and often correspondence makes reference to the decision-making authority of the CNSOPB. I would like to tap the expertise in DFO to help make the decisions. Generally I do not get the input and support I need in dealing with the Gulf. Perhaps a similar meeting to this should be set up to examine the issues in the Southern Gulf.

Last year I was very impressed with the Georges Bank RAP session. It was handled very skillfully, and included representation from NORIG 2000 and the oil industry. There was a good overview and discussion, and I would like to see a similar RAP session sooner rather than later on the Southern Gulf. Before anyone does work there, we need a good review of the anticipated effects. We have heard here that the effects of seismic exploration might be greater inshore than offshore, but the work of Fawley Research Labs and Turnpenny indicates almost the opposite. They conclude that the impact is less because there is greater sound attenuation and the fish tend to be more territorial. However there is no doubt that there are migrating species of groundfish through that area in the late summer and fall. So I invite you to give me some company. I suggest another SEEMAG type meeting or RAP session before we go much further.

Pat Stewart, Envirosphere

We have recognized that flocs exist on the shelf. We know how they move and behave, but I have never seen any work on weathering of these flocs. When developing models, an important question is how long do they last? Biodegradation is clearly at work but there is also dissolution and evaporation of the oils, desorption and so on. Has that been considered in the modelling efforts? I consider that it may be an important issue to assess in connection with your other work.

Len Zedel, MUN and Natural History Society of Newfoundland and Labrador

I took part in the Terra Nova Assessment and I wish this meeting had been held before that

review was undertaken.

I have been impressed by the work done to track what we expect to see, and the monitoring agencies have confirmed that the environmental interaction is as expected. However, does the existing monitoring scheme allow for the detection of the unexpected? At Terra Nova there is one satellite reference sampling station. Is that enough? I haven't heard much about the impact on birds or marine mammals. Also, on the topic of bioaccumulation, I am willing to agree that the concentrations of some of the nasty chemicals have been reduced to the point that they are not affecting individuals very quickly, but are there any problems with bioaccumulation? In addition, we know that there are many chemicals being introduced to this system in produced water.

Cal Ross

When the question of birds came up yesterday, we did say that we were having problems finding appropriate methods to study the subtle population level effects on birds. We may have been amiss not to mention the monitoring program of Memorial University and UNB. It involves a number of surface cruises to look at populations and also putting observers on rigs to look at the interaction between lights, flares and birds. It is a tough area to work in. The study has been underway for about a year, and in a year's time we should have results on the population census at sea and the interaction of birds with the rigs.

Ian McLaren

There is also good literature from the North Sea on the interaction of birds and flares.

Don Gordon

Reference was made to the RAP in December 1998 that was held to look at the potential environmental effects of exploration on Georges Bank. A technical report brings together all of the information that was presented. I can make copies available to those that want them.

Anver Rahimtula, MUN

We have heard about the chemical monitoring of offshore samples and the panel has suggested that there should be more biological monitoring. The presentations did not deal with that. Surely the goal is to identify the effect on the organism and therefore we should know more about that. It could be the physical characteristics of the organism, or the incidence of some disease such as cancer, inability to reproduce, effect on larvae, or another aspect. I have heard nothing about that and I cannot believe that measuring the concentrations of PAHs and metals year after year is really as important as the effects on the organisms.

Jocelyne Hellou

This is an international scientific concern with a large literature. We need to have background information on hydrocarbons, and we need to know what is the ongoing effect of industry, and what is the effect of effluents going into the ocean on organisms. Are they taking up the chemicals? And there are questions related to biomagnification in some cases. We need to be able to interpret data on fate and effects, especially those of short term toxicity tests. These give us information that is not always possible to interpret unless you do some lab experiments. In the field you cannot always be sure of the reason for the results of toxicity tests. If you take the animals and also analyse them for the chemicals, or the sediments and the water then you gain more understanding. You don't know how much the animals move, how long they stay at the same location, unless you have brought a bag filled with scallops or mussels and you know how long they have been there. You also have questions about the time required to reach equilibrium. Different chemicals take different times to equilibrate within

organisms. There are gigantic questions about how long chemicals can reside in fish, how long they can reside in the environment, how long it takes to have biomagnification. You have to be preventive and have a precautionary approach to environmental questions and that includes having a chemical view. I can suggest publications to read if you like.

Elizabeth May

One of the problems that confounds finding biological indicators for some emissions is that the chemicals may not be lipophilic. This is true for the human population as well, however that does not mean that the chemicals are not having an impact. You are not just looking at biological concentrations but also biological function, which is much harder to assess. With some substances such as mercury you can see bioaccumulation, but with many of the emissions that we are dealing with, the chemicals may be transitory, but it does not mean that they have no effect.

Mark Butler

I appreciate Andre d'Entremont's comments. I would encourage the government departments that participate in CNSOPB's advisory committee to be more open and forthcoming about their concerns. On the question of the RAP, it is very important how the question is defined and what you decide to look at. And finally, on the question of a RAP for the Southern Gulf, unless the license is withdrawn or there is some gesture of good faith beforehand, it may not be a fruitful endeavour. People are upset about the process to date so it may be better to withdraw the license and go back to the drawing board to establish a better climate for discussion.

Brian Giroux

The question was, "Where do we go from here". I find myself in a very fragmented regulatory environment where you may be regulated by the NEB, CNOPB or CNSOPB, and there are 12 or 14 different operators to deal with. There is a role for an event such as this to try to pull information together. We should not have to reinvent the wheel. Perhaps we could come up with some standards instead of duplicating research efforts. Is there a forum for co-ordinating research or is it all coming under different umbrellas? We have been undertaking research for 15-20 years and need to coordinate ourselves better. Some things have been done adequately while others have not been covered enough. Money is always tight no matter whether it comes from the government or the industry, so there is a role for another forum to take an overview of research in the interests of establishing a positive way forward.

Andre d'Entremont

There is some ESRF money that has been earmarked for a series of workshops and studies on cumulative effects monitoring for the eastern Scotian Shelf and eastern Grand Banks. An RFP for holding these workshops will be out soon.

Percy Haynes

We have had some experience with shrimp in the Gulf of St Lawrence. They are nearer the bottom of the food chain, and when their predators have gone, the shrimp survive and become plentiful. The scientists feel that when the cod come back the shrimp will decline. Maybe that is the type of event that is happening in the Gulf of Mexico.

I don't believe it is the rigs that draw the fish. They will hang around the wharf for the shade and food, even though, before the use of creosote poles was banned, the creosote was killing them. They didn't know that. For the oil company to say that the rigs draw the fish is completely out of line.

Jim Ray

In the Gulf of Mexico, the situation with respect to shrimp is quite different from what you described here. I don't think we could agree with your summation. Most of our bottom dwellers are snappers and groupers so I don't believe the data would support your analysis that competition and predation are the issues.

With regard to the platforms, most of the areas in the Gulf have a soft bottom, and over the past 30 years with all the exploration and development activity in the Gulf, a lot of hard substrate has been produced and this tends to attract certain fish. Those platforms have quite extensive bio-fouling communities on them with a large invertebrate community. There are also very large fish communities of different types, both pelagics and demersals around the platforms. Our industry is becoming mature on the shelf and now we are removing about 100 platforms a year. In light of this, some fisheries experts have been trying to determine the percentage of the snapper population that is related to those hard structures, and what the impact of removal will be on the red snapper industry in the Gulf. There is concern that the platform removal is causing habitat alteration so it has posed some interesting concerns.

There have been many studies in addition to chemical and biological studies done over the years in the Gulf of Mexico, such as incidence of cancer in fish, external lesions, external parasites, all of the indicators that you look for in studies of pollution stress, to see if there is any indication of these around the platform. In general they find that these are not out of line with what you find in each general population of a particular species. So all kinds of studies have been undertaken. As you proceed over the next few years, you may want to consider which types of studies you want to include in the work you will undertake to assess cumulative effects in Canadian waters.

Ian McLaren

I have been an ecologist since the 1950s, and I remember a comment from a great scientist Richard Levins that "the truth may rest at the intersection of many lies". Some of our perceptions are wrong and some are right but if we put them together we may come up with something worthwhile. Also in a book on genetics and development by John Maynard Smith I read recently, he said that reductionists on the right and holists are on the left. I notice that as I become older and more conservative, I find myself becoming more reductionist. I have discovered through a life time of trying that the big problems can only be answered by looking at small problems and hope that someday someone smarter than I can put them together into the bigger picture.

WORKSHOP SUMMARY

Understanding the Environmental Effects of Offshore Hydrocarbon Development: Workshop Summary and Reflections

Peter G. Wells, *Environmental Conservation Branch, Environment Canada*

Introduction

The oil industry has been exploring in earnest for oil and gas in the Atlantic Provinces since the 1960's. During the 1980s and 1990s, the pace of activity accelerated; three fields (Cohasset-Panuke, Hibernia, Sable) went into production, others such as Terra Nova on the Grand Banks are in the development phase, and one (Cohasset-Panuke) is now being decommissioned. Clearly, the oil and gas resources in Atlantic Canada in the offshore will be developed for decades to come, with enormous economic, environmental and social consequences for Atlantic Canadians. There is wide recognition that these non-renewable resources should be developed sustainably, taking all uses and values of the sea, its biota and its coastal communities into account.

The SEEMAG-BIO workshop in March 2000 addressed environmental effects monitoring (EEM) in the context of understanding the environmental effects of offshore hydrocarbon development in Atlantic Canada. It was the first focussed workshop on EEM needs related to oil and gas since the Canadian Society of Environmental Biologists Workshop in St. John's, Newfoundland, 1992 (Ryan 1993). The present workshop was very well attended, with just over 300 participants from many sectors. This shows the great interest and concern by many persons and institutions in this issue[5]. Not surprisingly, the pace of development and change is such that just three weeks after the SEEMAG workshop, the Canadian Association of Petroleum Producers and the Atlantic Canada Petroleum Institute held two workshops on research and development needs in Atlantic Canada (CAPP 2000)!

Highlights of the presentations and discussions are presented in Table 1. The summary is a set of discrete points, as presented at the meeting, with time and memory dictating some changes and improvements in the weeks that followed. The reader is of course encouraged to consider the whole proceedings!

Reflections on the SEEMAG Workshop

Some summary points are worth repeating, as well as some of the key facts and wisdom that transpired, and some guidance for the path ahead on EEM associated with the oil and gas industry in the Atlantic Provinces. It is hoped that the reader will also delve into the Proceedings and the topic as a whole, discuss the issues and develop informed opinions, and participate in the work and debates regarding the environmental and social implications of the industry on and along our coasts.

The Oceanic Environment, Marine Science and Ecotoxicology

Despite over 100 years of study, much remains unknown about the environment of the North-West Atlantic. Only a few of the fisheries resource species have a well-known biology and ecology, let alone the organisms at other trophic levels in the pelagic, demersal and benthic ecosystems. This complicates prediction of their abundances and distributions, and hence the detection of

[5] Other sources of information include Boesch and Rabalais (1987), Engelhardt et al. (1989) and GESAMP (1993), as well as the proceedings of the annual AMOP Technical Seminars in Canada, the ongoing series of the biennial API Oil Spill Conference in the USA, and various international seminars and conferences on the topic of offshore oil and gas.

population level effects linked to or caused by unusual perturbations in their environment. Their environment is often highly variable and changeable with the seasons and with storms, such as shown by subsurface current patterns on Sable Island Bank and with the movement of bottom sediments, respectively. This variability affects the fate (movement, final deposition) of waste materials from the oil platforms and complicates the sampling design and reproducibility of the EEM programs.

Fortunately, the dedicated marine science as illustrated by talks and posters at this meeting, though reduced in recent years, shows the progress in understanding both the oceanic environment and its biota, so essential for attempting EEM in the offshore. Also encouraging is the large array of instrumentation available for physical, chemical, geochemical and biological studies so essential for studying the offshore; this instrumentation is a tribute to the tenacity and skills of the local marine science and technology community, especially during many years of severe fiscal restraints.

Equally encouraging is the array of acute and sublethal assays that the marine ecotoxicologists can now bring to bear on water and sediment samples, and also deploy in the field. Sophisticated biochemical, physiological, growth and reproductive assays can be performed, demonstrating exposure to and effects from potentially harmful substances introduced into the sea from the oil and gas developments, as well as from ships, pipelines and coastal infrastructure. Associated with these developments is an enhanced modeling capacity, invaluable (indeed, essential) to all of the research and monitoring studies.

The Atlantic offshore is imperfectly known, highly variable, complex and hence not always predictable—a challenging backdrop for essential prospective and retrospective EEM. Atlantic Canada is fortunate to have the base of a significant and dedicated scientific and technical capacity (albeit, in great need of recruits and resources) that can now be deployed in support of effective and comprehensive EEM.

Environmental Effects Monitoring (EEM)

Four major EEM programs in the Atlantic offshore have been or are being conducted (see Table 1 and the foregoing abstracts). All programs are well organized, building on the strengths of previous work and experiences (e.g. NRC 1990, Ryan 1993) and on the region's capacity in oceanography, ocean engineering, ecotoxicology and environmental monitoring.

It is essential to link EEM with ecological risk assessment (ERA), conceptually and formally. The process of ERA is now well developed. Each EEM program should take a risk assessment approach, ensuring the inclusion of suitable hazard evaluation, exposure assessment and dose-response assessment studies and endpoints (Landis and Yu 1999). The current choice of VECs is appropriate but does not negate concern about the many (the majority!) unmonitored species in the system, a fact that should be acknowledged openly. Most species are not monitored and many have ecological roles that are only partially understood, not understood or even studied. There is insufficient state of the art ecology in or integrated with the EEM programs, and no accommodation for associated "curiosity R and D" (CAPP 2000) that may provide many dividends of methods and toxicity "endpoints" useful to EEM.

In addition, we cannot ignore the cumulative effects question—it came up many times during the workshop. We must consider more carefully what is meant by the term, and then address cumulative change both within the EEM designs and conceptually-theoretically-experimentally. The question gains importance as offshore sites accommodate multiple oil developments, pipelines or land facilities.

Finally, is the EEM anticipatory, prospective, or early warning in nature? What is being monitored is what is expected to respond to the various perturbations due to wastes, oils, noise, etc., not to what is unexpected. There is too little consideration of what may be responding to changes in the environment, but that goes undetected. At the very least, this topic should be given attention by graduate researchers. It is comforting that few surprises have been detected in the EEM thus far, but a high comfort range does not belong in well-run EEM programs!

Societal Concerns—Societal Responsibility

The big message from the workshop was that trust and communication are essential in well-run EEM programs. Everyone on our coasts should have the opportunity to be included in discussions and decisions about the future of the industry, the developments and their locations, the EEM itself, and the review processes related to impacts either ecological or social. The industry has been open, indeed was mandated to be so under the various governmental agreements and the energy panel hearings and conclusions. For the Sable projects, SEEMAG clearly and openly seeks commentary and critiques so as to facilitate appropriate and rigorous EEM for the lifetime of the projects.

Acknowledgments

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Table 1.
Workshop Summary and Reflections Prepared by Peter G. Wells

1. Scope and Objectives of EEM in the Offshore (SOEI-EMP)

- To provide early warning of undesirable environmental change.
- To verify earlier impact predictions.
- To improve understanding of cause-effect relationships (project-environment).
- To evaluate and confirm effectiveness of mitigation and regulatory compliance.

2. Introduction (John Brannan, SOE Inc.)

- Sharing information is key to successful environmental protection and protecting ecological sensitivities.

3. Overview of Activity, Research and EEM (Don Gordon)

- Regulatory framework is in place.
- There is a large scientific resource of knowledge and expertise to draw upon in support of EEM (e.g. Canada, international, various research institutions, funding).
- Four EEM programs are underway in Atlantic Canada.

4. EEM and 3-Ps of Ecotoxicology

- Remember the 3-P's of ecotoxicology - exPosure, Partitioning, Potency (McCarty and Mackay 1993). These apply to EEM.
- Exposure is the key variable(s) and probably the most difficult to describe.

5. Science and EEM Programs

- Exposure: Presentations by Hannah, Li, Muschenheim.
- Effects: Presentations by Zwanenberg, Payne, Cranford, Lee.
- EEM (part of ERA): Presentations by MacNeil, Taylor, Hurley, Williams.

6. Transport and Dispersion (Charles Hannah)

- Modeling is very important to EEM - it aids in impact predictions.
- Learn from inference, e.g. salinity and temperature data show that Scotian Shelf has 3 major mixing areas, and that eastern Shelf has changed more (at 20-50m depth) than the western Shelf.
- Circulation and dispersion modeling
  - Circulation and BBLT family of models help determine where fine particles of drilling muds go - i.e. their transport and fate,
  - Helps understand key factors to dispersion and how impacts might change with season.
  - Aids in predicting where impacts may or may not be expected, hence where to monitor.

7. Seabed Stability and Sediment Dynamics on SIB (Mike Li)

- Clear linkages to EEM design and conduct e.g. seabed on Sable Island Bank (SIB) is active - storms change sediment dynamics and patterns.
- Value of new instruments e.g. RALPH.

- Value of modeling sediment transport and patterns e.g. buildup, erosion.
- Storms dominate sediment transport.
- Links to EEM Programs:
  - Water column events influence the mobile sediment layer depths, hence what is collected in a sediment core.
  - Sediments change from year to year - must be accounted for in EEM design and sampling!

8. Fates of Drilling Wastes (Kee Muschenheim)

- Fate of drilling waste fine particles is important as they cause adverse effects, they flocculate, they allow study of BBL.
- New EEM method - particle size analysis is a tracer of muds and cuttings.
- New instruments - e.g. BOSS, SOB, CAMPOD, CABLE, MIMS, BRUTIV.
- Storms increase bottom currents and move sediments and drilling wastes.
- Research is important - find the unexpected e.g. plume can stay in water column.
- Research-EEM-industry link e.g. instruments developed for research are useful to industry doing EEM.

9. Biological Resources—Scotian Shelf (Kees Zwanenburg)

- Provides biophysical context for EEM.
- Only few biota are well-known.
- Can we separate the human-induced changes from natural changes? e.g. fishing pressure vs. temperature change.
- "How are we going to monitor the changes and whose responsibility is it?"
- Need better survey data, using high resolution techniques, on pelagic fish and benthos living in small reference areas on east and west Sable Bank.
- For EEM, provides case for using individual-level rather than population-level responses.

10. Biological Effects Research (Jerry Payne)

- Individual organism approaches are useful for defining impact zones in water and sediments, e.g. MFOs, bioaccumulation, tainting, condition index, EDC responses, histopathology, microscale toxicity tests.
- Effect zone at Hibernia appears "very localized", BUT continue monitoring, especially with resource species.

11. Biological Effects of Drilling Wastes (Peter Cranford)

- Strong case for using single species in EEM e.g. sea scallops, many toxic responses.
- Feeding is a sensitive response to muds.
- Models - useful for overlaying toxicity data from individual exposures on modeled population predictions.
- At Hibernia:
  - Shellfish monitors measure contamination, bioaccumulation, tainting, toxicity.
  - Innovative monitoring techniques, e.g. HARP scallop frames for study of cumulative effects of field exposures to platform discharges.
  - Spatial features of drilling mud contamination are detected.

12. Produced Water and Spill Countermeasures (Ken Lee)

- Produced water (PW)
  - Very complex, variable, toxic (many assays), and its particles sink and surface.
  - Ecological risk assessment (ERA)

approach is needed for offshore EEM.

- Oil spills
  - Bioremediation-enclosure experiments can assist EEM, addressing risks to shorelines.

13. EEM at Cohasset-Panuke (Mark MacNeil)

- EEM program
  - Two way interaction (project-environment).
  - Important research link e.g. prognostic 3-D modeling of physical system, waves.
  - Mussel tainting study - a valuable VEC. Discharges caused taint within 500m of rig; system "recovered" after discharges ended.
  - Seabird and litter surveys on Sable Island.

14. EEM at the SOE Inc. Project (Geoffrey Hurley)

- A VEC-based EEM
  - Covers water column, sediments & organisms in a very dynamic environment.
  - Design is flexible.
- Hydrocarbons enter sediments but they are transient.
- Barium is detected in SPM out to 3000m.
- Cuttings are in localized mounds near rigs.
- Effects
  - Chemical burdens and taint (mussels) and toxicity are monitored.
  - Sand dollars dominate the benthos.
  - Variable sediment toxicity.
  - No taint, odor detected in mussel studies.
  - Systematic observations of birds and mammals.
  - Most effects noted within 250 m of rigs.

15. EEM at Hibernia (Dave Taylor)

- Connect all ongoing EEM programs, exchange information and periodically review study designs.
- Design is hypothesis-based.
- Includes fish taint; sediment chemistry-toxicity-biology; seabirds.
- Open to improvements.
- Results of monitoring:
  - Hydrocarbons and metals decline within 1000m.
  - PAHs below detection limits.
  - Sediment non-toxic.
  - No evidence of fish(plaice) taint.
  - Conclusions- no impacts or tainting.
  - Lessons- change fish; collect more sediment; continue to monitor seabirds.

16. EEM at Terra Nova Project (Urban Williams)

- Applying rigorous EEM strategy.
- Taking VEC approach to baseline studies, e.g. water, sediment quality; scallops; seabirds; TRIAD on sediments; taint.
- Building in ability to re-evaluate EEM approach and design.
- Involving many stakeholders.

17. Workshop Highlights—Day One (Participants)

- More attention is needed to:
  - Exposure: Composition and effects of produced water discharges at Hibernia, incl. oil droplets.
  - Exposure: Levels of chemicals in fish tissues.
  - Effects: Potential for cumulative effects at air-water interface, and on seabirds.
  - Effects: Methods for monitoring seabird health.
  - Risk Assessment:: How to use EEM data?

18. Workshop Highlights—Day One (Don Gordon)

- Several EEM needs:
  - Understanding of natural variation of all aspects of offshore environment.
  - Careful design and statistics.
  - Combined lab-modeling-field approaches.
  - Picking the right variables - sites differ.
- EIAs were conservative - most "ecosystem responses" to date were predicted.

19. Poster Highlights

- Research shown in 25 posters represents current basic and applied marine science in the Atlantic Provinces, from chemical oceanography to ecotoxicology to EEM approaches, and reflects our combined capacity to support and conduct world-class EEM programs.

20. Ecological Framework for EEM—a Perspective (Jim Ray)

- Develop trust.
- Have an open process, with access to data.
- Use the literature - do not redo studies.
- Include recovery studies in EEM.
- Link EEM to ERA (ecological risk assess.). Consider other factors - the ocean is a complex environment.
- Ensure decisions are data driven.
- Learn from past weaknesses of EEM (e.g. data quality; inadequate ref. stations).
- Build upon past lessons (e.g. ask right questions; use review boards).
- Improve (e.g. field verification; real-world exposures in ecotoxicological experiments).

21. Role of EEM—Other Perspectives (Panel)

- EEM requires TRUST of all players.
- Address major concerns - cumulative effects, contaminants in natural foods.
- Encourage legitimate participation of NGOs in the process of EEM.
- Take an eco-centric approach to EEM.
- Continue public consultation input into EEM e.g. SEEMAG.
- Consider cumulative impacts in context of other activities in coastal zone and on land.
- Improve regulatory use of EEM.

22. Where To Go From Here? (Open Discussion)

- Consider impacts of oil and gas industry in the context of other pressures (e.g. fishing, land-based activities) on the sea. Look for cumulative impacts and changes - reversible and irreversible.
- Ensure conservation is part of EIA and EEM goals, and is built into management.
- Source reduction of pollution can work.
- Consider the nearshore impacts too - e.g. aesthetics, fisheries, social changes.
- Develop more trust and improve communication between the players.
- Consider the whole chain of events and changes (environmental, social, economic), not parts in isolation.
- Develop new technologies for EEM.
- Monitor more individual species, and their populations and communities.
- Address effects of seismic exploring.
- Address the unexpected - birds, long-term.
- Apply the precautionary principle.
- Clarify EEM results for regulators.

23. The Way Forward - EEM and the Offshore—Atlantic Canada

- Continue close integration of monitoring and relevant research programs.
- Ensure rigorous sampling designs.
- Meet periodically to exchange data and improve EEM capacity in Atlantic Canada.
- Maintain trust and communication.

Appendices

APPENDIX A

WORKSHOP PROGRAM

Agenda

Thursday, March 2

090	Welcome *John Brannan, General Manager and President, SOE Inc.* Opening remarks by Workshop Co-Chairs *Don Gordon,* Marine Environmental Sciences Division, DFO* *Cal Ross,* Senior Environmental Advisor, SOE Inc.*
0915	Hydrocarbon developments off the East Coast, and how we got here: a retrospective overview of industry activity, scientific research and the development of environmental effects monitoring programs *Don Gordon*, Marine Environmental Sciences Division, DFO*
0930	What we are trying to protect: an overview of the biological resources in the Sable Island Bank and Grand Banks regions *Kees Zwanenburg, Marine Fish Division, DFO*
1000	Transport and Dispersion on Offshore Banks *Charles Hannah, Ocean Sciences Division, DFO*
1030	Break
1045	Environmental effects monitoring at the Cohasset/Panuke project *Mark MacNeil, Vice President and Senior Oceanographer, Coastal Ocean Associates*
1100	Seabed Stability and Sediment Dynamics Research on Sable Island Bank *Mike Li, Geological Survey of Canada (Atlantic)*
1130	Environmental effects monitoring at the Hibernia project *Dave Taylor, Hibernia*
1200	Research on the fates of drilling wastes *Kee Muschenheim*, Acadia Centre for Estuarine Research*
1230	Lunch
1330	Research on the biological effects of offshore hydrocarbon development. *Jerry Payne, Northwest Atlantic Fisheries Centre, DFO*

1350	Research on biological effects of drilling wastes *Peter Cranford, Marine Environmental Sciences Division, DFO*
1415	Environmental effects monitoring at the Sable Offshore Energy project *Geoffrey Hurley*, SOE Inc. and SEEMAG member*
1515	Break
1530	**Environmental Assessment of Potential Produced Water Impacts and Developments in Oil Spill Countermeasures** *Ken Lee, Marine Environmental Sciences Division, DFO*
1600	Environmental effects monitoring at the Terra Nova project *Urban Williams, PetroCanada*
1630	Discussion
1700	End of day wrap-up: key themes
1715-1815	Reception for workshop participants sponsored by Canadian Association of Petroleum Producers

Friday. March 3

0830	Poster session
0930	The ecological framework for environmental effects monitoring: a perspective from outside the region *Jim Ray, Equilon Technolgy*
1015	Break
1030	The role of EEM as seen by: *Mark Butler, Ecology Action Centre* *Brian Giroux*, Scotia-Fundy Mobile Gear Fishermen's Association* *Inka Milewski, World Wildlife Fund* *Chris Milley, Mi'kmaq Fish and Wildlife Commission* *Charles Warner*, Strait of Canso Fishermen's Liaison Committee*
1200	Lunch
1245	Where should we go from here? Open mike discussion. *Moderator: Ian McLaren*, George Campbell Professor of Biology Emeritus, Dalhousie University*
1415	Pulling it all together: Personal reflections from workshop rapporteur *Peter Wells*, Coastal Ecosystems, Environment Canada*
1430	Closing remarks *Workshop Co-Chairs*
1445	Workshop ends

* Denotes SEEMAG member

APPENDIX B

GULF OF MEXICO PRODUCED WATER BIOACCUMULATION STUDY: DEFINITIVE COMPONENT

Executive Summary

The objectives of the Definitive Component of the Gulf of Mexico Produced Water Bioaccumulation Study were to

- determine whether statistically significant bioaccumulation of target chemicals in produced water occurs in the edible tissues of resident fishes and invertebrates at representative Gulf of Mexico offshore platforms that discharge more than 4,600 barrels per day (bbl/d) of produced water relative to non-discharging platforms; and
- evaluate the ecological and human health implications of observed concentrations of target chemicals in edible tissues of fishes and invertebrates collected near offshore platforms in the Gulf of Mexico.

The study was performed in response to a U.S. Environmental Protection Agency (EPA) Region VI National Pollutant Discharge Elimination System General Permit requirement and was funded through the Offshore Operators Committee. The Definitive Component was designed to compare concentrations of 60 target chemicals (metals, radium isotopes, phenol, bis(2-ethylhexyl)phthalate [BEHP], monocyclic aromatic hydrocarbons, and polycyclic aromatic hydrocarbons [PAHs]) in edible tissues of fish and bivalve mollusk species from two discharging/non-discharging platform pairs. The two discharging platforms discharged approximately 7,000 and 11,000 bbl/d of treated produced water. Samples of produced water, ambient seawater, and the selected fish and mollusk species were collected from the two platform pairs during two cruises, one in the spring and one in the fall. The samples were analyzed with state-of-the-art methods that included a rigorous quality assurance/quality control program. Low detection limits for the target chemicals were achieved that made it possible to determine if the target chemicals were present in edible tissues at concentrations of ecological and human health concern. Despite the low detection limits, the target organic chemicals were not present in most tissue samples at concentrations above the method detection limits. Radium isotopes were detected in 55% of the tissue samples, but at concentrations below EPA risk-based concentrations (RBCs). The four target metals were present in tissues at concentrations typical for marine animals from clean marine environments.

There was no evidence of bioaccumulation from produced water of mercury, BEHP, fluorene, and benzo(a)pyrene. The evidence for bioaccumulation from produced water was weak, inconclusive, doubtful, or contradictory for arsenic, barium, cadmium, radium isotopes, phenol, and total PAHs. Based on a review of the published literature, none of the EPA-specified target chemicals were present in edible tissues at concentrations that might be harmful to the fishes and mollusks. Two of the target chemicals (arsenic and cadmium) were present in a few edible tissue samples, particularly mollusks, at concentrations slightly higher than RBCs. However, these chemicals were present in tissues in nontoxic forms and do not pose a health hazard to consumers of bivalve fishes and mollusks from the northwestern Gulf of Mexico.

APPENDIX C

METALS AND ORGANIC CHEMICALS ASSOCIATED WITH OIL AND GAS WELL PRODUCED WATER: BIOACCUMULATION, FATES, AND EFFECTS IN THE MARINE ENVIRONMENT

Executive Summary

The current National Pollutant Discharge Elimination System (NPDES) General Permit (No. GMG290000) for discharges of 4,600 barrels/day or more of treated produced water from offshore oil and gas production platforms to offshore waters of the western Gulf of Mexico requires a site-specific bioaccumulation monitoring study. The offshore oil industry is participating in a U.S. Environmental Protection Agency-approved, generic bioaccumulation study that includes a more thorough evaluation of a smaller number of geographically distributed offshore produced water discharges. This report was prepared for the Gulf of Mexico Offshore Operators Committee to evaluate the scientific data concerning the bioaccumulation of chemicals commonly found in produced water to aid in interpreting the bioaccumulation monitoring data. This report evaluates the potential for bioaccumulation of the chemicals identified in the NPDES permit that require bioaccumulation evaluation and several other chemicals of environmental concern frequently found in treated produced water that is discharged to ocean waters of the Gulf of Mexico. The chemicals evaluated in this report include

- metals: arsenic, barium, cadmium, mercury, chromium, copper, lead, and zinc;
- naturally occurring radioactive material: radium-226 and radium-228;
- monocyclic aromatic hydrocarbons: benzene, toluene, ethylbenzene, and xylenes;
- polycyclic aromatic hydrocarbons (PAHs): fluorene, benzo(a)pyrene, total PAHs;
- miscellaneous organic chemicals: phenol and bis(2-ethylhexyl)phthalate (BEHP).

All these chemicals, except BEHP, are natural components of oil and gas well produced water and are natural trace ingredients of sea water.

The metals evaluated here are all, with the exception of mercury, nearly always found in produced water from the Gulf of Mexico. Mercury is only occasionally detected in produced water. These metals also are natural constituents of clean sea water. The metals most frequently found in produced water at concentrations substantially higher (1,000-fold or more) than their natural concentrations in clean sea water are barium, cadmium, chromium, copper, iron, lead, nickel, and zinc.

Some produced waters from the Gulf of Mexico contain concentrations of naturally occurring radioactivity higher than that encountered in sea water and brackish water. The most abundant radionuclides in produced water are radium-226 and radium-228. Concentrations in produced water may be up to 5,000 times higher than natural concentrations in sea water.

Monocyclic aromatic hydrocarbons (consisting primarily of benzene, toluene, ethylbenzene, and xylenes: BTEX) and PAHs are natural constituents of crude petroleum and dissolve from the oil into the produced water. Concentrations of BTEX are higher than those of PAHs in produced water and the relative concentration decreases with increasing molecular weight. High molecular weight, four- through six-ring PAHs are present at trace (sub-parts per billion) concentrations, when they can be detected at all.

There are also traces of BTEX and PAHs in clean sea water, much of them derived from deposition of airborne hydrocarbons from combustion sources, and from natural oil and gas seeps that are abundant in the northwestern Gulf of Mexico.

Phenol often is present at high concentrations in produced water. BEHP is not a natural ingredient, nor is it added intentionally to produced water. It is a ubiquitous trace contaminant of the environment, being derived from leaching of plasticizers from plastics. Any traces detected in produced water probably are from this source.

For each of the chemicals, this report discusses the information available from the scientific literature on

- its occurrence in sea water;
- its occurrence in marine sediments;
- what is known about its tendency to bioaccumulate in tissues of marine organisms;
- concentrations in tissues of marine organisms in the Gulf of Mexico and in the other oceans of the world; and
- its toxicity to marine organisms.

Based on this information and information on the concentration of each chemical in Gulf of Mexico produced water, a judgement is made about the relative risk to the health of marine ecosystems and human consumers of fisheries products from these chemicals in produced water discharged to the ocean.

As a general rule, concentrations of metals in tissues of marine organisms in the Gulf of Mexico and in the immediate vicinity of offshore discharges of produced water are in the normal range and do not show evidence of bioaccumulation to potentially toxic levels for the organisms themselves or their consumers, including man. A review of the concentration of each metal in typical Gulf of Mexico produced water and its potential for bioaccumulation and toxicity reveals that only two metals have the potential to pose a health risk to marine organisms and their consumers. These metals are cadmium and copper. Any adverse effects of these metals, if they occur at all, are likely to be very localized in the immediate vicinity of the produced water discharge and affect mainly plants and animals living attached to submerged platform structures.

Radium isotopes, although often abundant in produced water, do not appear to bioaccumulate in the tissues of marine animals following discharge of produced water to the ocean. Radium is quantitatively removed from sea water by coprecipitation with barium as barium sulfate upon mixing of produced water (rich in barium) with sea water (rich in sulfate). Radium is not toxic to marine organisms at the concentrations at which it occurs in produced water or in the receiving water environment of a produced water discharge. Therefore, it does not represent a hazard to marine organisms near produced water discharges, nor to human consumers of fishery products.

Phenol from produced water has a low potential to bioaccumulate and both phenol and BEHP are rapidly metabolized and excreted by marine animals. Therefore, these chemicals are not considered hazardous to marine organisms. BTEX are abundant in produced water, but disappear very rapidly from the receiving water environment through evaporation, dilution, and biodegradation. They are only moderately toxic and do not biaccumulate to high concentrations in tissues of marine animals. They are not transferred to man through consumption of fishery products. Therefore, BTEX in produced water does not pose a health risk to marine organisms or human consumers of fishery products.

PAHs in produced water, represented by the low molecular weight PAH, fluorene, and the high molecular weight PAH, benzo(a)pyrene, have a low or moderate potential risk to marine

organisms and human consumers of fishery products. The low molecular weight two- and three-ring PAHs often are relatively abundant in produced water, concentrations decreasing with increasing molecular weight. They have a tendency to bioaccumulate and often are persistent in sediments near produced water discharges. Because they are toxic, they pose a moderate risk to organisms near the produced water discharge or in sediments near the outfall. High molecular weight four- through six-ring PAHs, on the other hand, are rarely present in produced water at greater than trace (sub-parts per billion) concentrations. Although some, such as benzo(a)pyrene, are known or suspected mammalian carcinogens and readily bioaccumulate, their extremely low concentrations in produced water renders them a low risk to marine ecosystems and human consumers of fishery products from the vicinity of produced water discharges. The major source of high molecular weigh PAHs in offshore waters of the Gulf of Mexico is soot from various combustion sources. PAHs associated with soot are tightly bound to the particles and are not readily bioavailable to marine organisms. These compounds are not accumulated efficiently from the food and are biodegraded rapidly in the tissues of most marine animals; therefore, they do not biomagnify in marine food webs and do not pose a potential hazard to fish that consume biofouling organisms from submerged platform structures.

APPENDIX D

GULF OF MEXICO PRODUCED WATER BIOACCUMULATION STUDY: PLATFORM SURVEY COMPONENT

Executive Summary

The National Pollutant Discharge Elimination System General Permit for the Western Gulf of Mexico Outer Continental Shelf (GMG 290000) requires bioaccumulation monitoring for facilities discharging more than 4,600 barrels/day (bbl/d) of treated produced water. The objective of the Platform Survey Component of the bioaccumulation study was to determine the concentrations of 12 U.S. Environmental Protection Agency (EPA)-specified target chemicals in edible tissues of fishes and invertebrates collected in the immediate vicinity of produced water discharging and non-discharging platforms from different regions of the western Gulf of Mexico. Two species of fish were sampled from 11 discharging/non-discharging platform pairs, and oysters, blue crabs, and 1 species of fish were collected for analysis from 1 discharging/non-discharging platform pair. The platform pairs consisted of Definitive Component Platforms and platforms located in four areas: high platform density; influenced by the Mississippi River; water depths less than 10 m; and off the Texas coast. Edible tissues of oysters, crabs, and fishes were analyzed by advanced, sensitive methods for arsenic, cadmium, mercury, ^{226}Ra and ^{228}Ra, benzene, toluene, ethylbenzene, phenol, bis(2-ethylhexyl)phthalate (BEHP), fluorene, and benzo(a)pyrene (BAP). The target metals were measured in 496 tissue samples; target volatile organic chemicals were measured in 494 tissue samples, target semivolatile organic chemicals were measured in 495 tissue samples; and target radionuclides were measured in 495 tissue samples. This represents the largest existing database of chemical residues in tissues of marine animals from the western Gulf of Mexico.

The analytical methods provided method detection limits (MDLs) well below screening level risk-based concentrations (RBCs) for protection of human consumers of fishery products. Nevertheless, most of the analytical results for organic chemicals in tissues were below the MDLs. The volatile aromatic hydrocarbons, benzene, toluene, and ethylbenzene were not detected in 97% of tissue samples. In the few samples in which a volatile aromatic hydrocarbon was detected, the concentration was orders of magnitude below the RBC. Fluorene was not detected in 89% of tissue samples. The highest measured concentration was 0.03% of the RBC. BAP was not detected in over 97% of 494 tissue samples. Phenol was not detected in 86% of tissue samples. Most of the other tissue samples in which phenol was detected were collected from non-discharging platforms and contained phenol concentrations 50% or less of the RBC. BEHP was not detected in 90% of tissue samples. It was found in some blank samples, indicating that, when present, it may be the result of sample contamination during collection, processing, and analysis. Tissues containing detectable concentrations of BEHP were collected about equally from discharging and non-discharging platforms. The tissue BEHP, if not an artifact, was derived from a source other than produced water, because BEHP is not a known component of produced water. Arsenic and mercury were detected in all tissue samples. Concentrations were typical of those in tissues of marine animals from clean marine environments throughout the world. All tissue samples contained arsenic concentrations higher than the RBC. Arsenic is

abundant in edible tissues of all marine animals and is present in non-toxic organic forms. There was no apparent difference in mercury and arsenic concentrations in tissues of marine animals from discharging and non-discharging platform sites. Cadmium was detected in 82% of 496 tissue samples. Cadmium concentrations were comparable in edible tissues of marine animals from discharging and non-discharging platforms. Total radium (sum of ^{226}Ra and ^{228}Ra) was detected in less than half of the tissue samples.

The results of this study indicate that there is no relationship between the proximity of marine animals to offshore produced water discharges and concentrations in their edible tissues of the 12 EPA-targeted chemicals. The concentrations of the chemicals in edible tissues of marine animals from the western Gulf of Mexico are below concentrations that might represent a hazard to the marine animals themselves or their consumers, including man.

APPENDIX E

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APPENDIX F

List of Acronyms and Definitions

ADCP	Acoustic Doppler Current Profiler
AMOP	Arctic Marine Oilspill Program
ANOVA	analysis of variance.
API	American Petroleum Institute
bbl	benthic boundary layer.
bblt	benthic boundary layer transport.
BIO	Bedford Institute of Oceanography.
BOSS	benthic organic seston sampler.
BRUTIV	bottom-referencing unmanned towed instrumented vehicle.
CABLE	Compact Aquatic Boundary Layer Explorer.
CAPP	Canadian Association of Petroleum Producers.
CEAA	Canadian Environmental Assessment Agency.
CNOPB	Canada Newfoundland Offshore Petroleum Board.
CNSOPB	Canada Nova Scotia Offshore Petroleum Board.
COGLA	Canada Oil and Gas Lands Administration.
Copan	Cohasset and Panuke oilfields.
Cr	chromium
CSEB	Canadian Society of Environmental Biologists
CTD	conductivity - temperature - depth
DFO	Department of Fisheries and Oceans.
DW	drilling wastes.
EA	environmental assessment
EAC	Ecology Action Centre.
EC	Environment Canada
EDC	endocrine disrupting compound.
EEM	environmental effects monitoring.
EIA	environmental impact assessment.
EIS	environmental impact statement.
EM	environmental monitoring
EMP	environmental management plan.
ERA	ecological risk assessment.
ESRF	Environmental Studies Revolving Fund.
FLC	Fisheries Liaison Committee.
FPSO	Floating Production Storage and Offloading.
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GSCA	Geological Survey of Canada - Atlantic.
HCs	hydrocarbons.
ICES	International Council for Exploration of the Seas.

ITOSS	In-situ Treatment of Oiled Sediment Shorelines Program.
MFOs	mixed function oxygenases.
MFWC	Mi'kmaq Fish and Wildlife Commission.
MIMS	Moored Instruments Monitoring System.
MPA	Marine Protected Area
MUN	Memorial University of Newfoundland.
NEB	National Energy Board.
NGOs	non-government organizations.
NRCan	Natural Resources Canada (formerly Department of Energy, Mines and Resources).
NSERC	National Scientific and Engineering Research Council.
OBS	optical backscatter sensors (or signatures).
OCC	Offshore Operators Committee (Gulf of Mexico)
PACs	polycyclic aromatic compounds.
PAHs	polycyclic aromatic hydrocarbons.
PERD	Panel on Energy Research and Development.
PSA	Particle Size Analysis techniques.
PW	produced water.
QA/QC	quality assurance/quality control
QRB	quality review board
RFP	request for proposals
SBM	synthetic oil-based muds.
SEDTRANS	sediment transport models.
SEEMAG	Sable Offshore Energy Environmental Effects Monitoring Advisory Group.
SIB	Sable Island Bank.
SMS	Imagenex Scour Monitoring System.
SOB	son of BOSS (second version of BOSS).
SOEI	Sable Offshore Energy, Inc.
SOEP	Sable Offshore Energy Project.
SOP	standard operating procedure
SPM	suspended particulate matter.
TIE	toxicity identification evaluations
TPH	total petroleum hydrocarbons.
TRIAD	refers to a system of monitoring using chemistry, toxicity and ecology studies.
UCCB	University College of Cape Breton
UKOOA	The Oil and Gas Producers Association (UK)
UNB	University of New Brunswick
VEC	valued ecosystem component.
WBA	water-based muds.
WWF	World Wildlife Fund

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